PRODUCTIVE LAND USE SYSTEMS

Haiti

SOUTH-EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT
AND
AUBURN UNIVERSITY

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The Effects of Leucaena Hedgerow Management on Maize and Hedgerow Biomass Yields over Two Years of Cropping

by

Lionel Isaac, Dennis A. Shannon, Frank E. Brockman and Carine R. Bernard

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We are grateful to USAID for funding this research, to CARE for supporting the continuance of the Agroforestry trials in PLUS and to PADF staff for their moral encouragement in carrying these trials through to completion.

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LIST OF ACRONYMS

AFII	Agroforestry II
CARE	Care International, a project implementor
M&E	Monitoring and Evaluation
PADF	Pan American Development Foundation, a project implementor
PLUS	Productive Land Use Systems
SAS	Statistical Analysis Systems
SECID	South-East Consortium for International Development
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

Objectives:

The objectives of the study were to identify optimum hedgerow management practices for alley cropping in order to optimize crop yield and hedgerow biomass production under lowland conditions in Haiti.

Factors Tested:

The following treatment combinations were tested: three pruning utilization treatments, (1) prunings removed, (2) prunings applied as mulch and (3) prunings incorporated at maize planting, with subsequent application as mulch; by three pruning regimes, (a) at planting and 30 days after planting (DAP), (b) at planting and 40 DAP and (c) at planting, 30 DAP and 60 DAP. A dry wall treatment was included as a control

Findings:

Stone Walls vrs. Alley Cropping

- During the first year of the trial, higher yields were obtained with the stone wall treatment than with alley cropping. During the second year, the best alley crop treatments gave the same yield as the stone wall control.
- Maize yields steadily declined over time in the stone wall control treatment, but remained steady in the best alley cropping treatments.
- The amount of nitrogen contributed by the hedgerow prunings is estimated to be substantial.

Hedgerow Management

Hedgerow pruning regime and mode of utilization of prunings had important effects on crop and biomass yields. The accompanying figure shows the effects of these

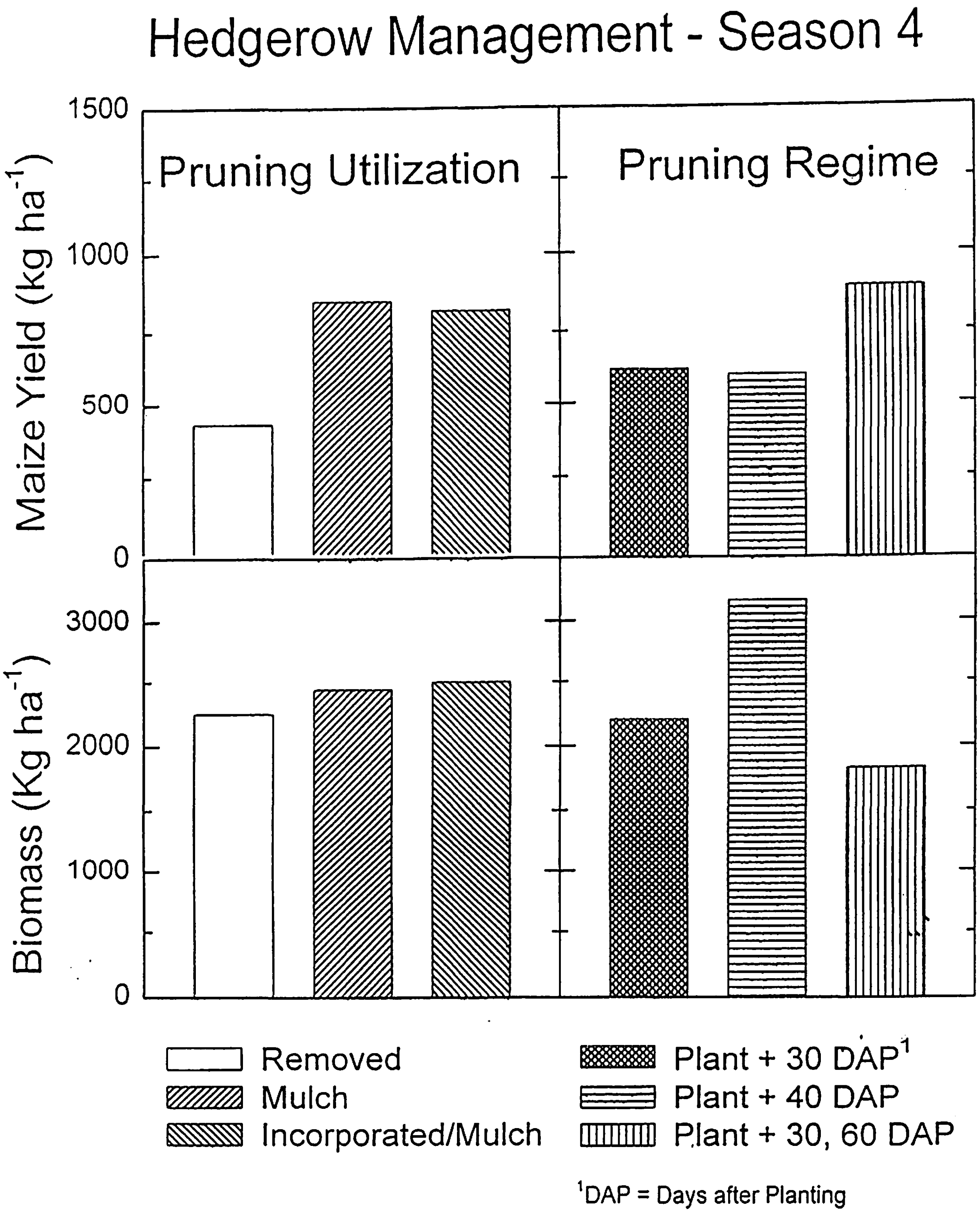


Figure. The effect of pruning use and timing of prunings on maize yield and hedgerow biomass production in fourth season.

factors in the fourth growing season:

- Removal of hedgerow prunings resulted in lower maize yields but had little effect on hedgerow biomass yields.
- Incorporation of the first pruning at planting time did not improve maize yields, as compared to prunings used as mulch.
- Pruning three times, at planting and 30 and 60 days after planting, resulted in higher maize yields than pruning only twice.
- Pruning three times resulted in lower biomass production than pruning only twice.
- Highest hedgerow biomass yields were obtained by pruning at planting and at 40 days after planting.

Implications for Haitian farmers:

- Use of stone walls as a barrier to erosion is of itself inadequate to maintain yields over time.
- Removal of hedgerow prunings to feed livestock also results in declining yields over time without other means of replenishing nutrients and organic matter in the soil.
- Application of hedgerow prunings to the soil, either as mulch or incorporated, sustains crop yields.
- Alternative strategies for meeting livestock forage needs are required if the goal is to improve soil fertility.

Recommendations for PLUS Extension Effort:

- PLUS should continue to encourage the planting and maintaining of hedgerows.
- PLUS should emphasize the importance of soil application of hedgerow prunings to sustain crop yields.
- PLUS should emphasize the importance of timeliness of hedgerow pruning.

- PLUS should identify other means for meeting livestock forage requirements which complement rather than compete with cropping needs.

<u>Recommendations for Adaptive Research and M&E</u>:

- Results from the hedgerow management trial should be combined with on-farm data to refine the financial assessment of hedgerows.
- Analysis of leaf and branch samples for nitrogen content is needed to more accurately estimate the contribution of hedgerow biomass to the crop under various hedgerow management systems.
- Greater attention should be given to hedgerow management and pruning use in M&E studies of hedgerows.
- The present trial should continue in order to determine management effects over a longer period.
- Testing is needed at other locations to refine recommendations on pruning regime under varying rainfall and soil conditions and with other crops.

REZIME KREYOL

Objektif:

Objektif étid sa-a se chèche, nan kondisyon peyi Dayiti, pi bon jan pou travay ak ranp vivan pou ogmante randman kilti nan mitan ranp yo ak randman ranp yo tou.

Ki sa ki te etidye:

Nou te konpare kèk jan pou travay ak ranp lesena. Nou te etidye twa fason pou itilize fèy ak branch vèt lesena ki nan ranp yo: (1) retire nan jaden an fèy ak branch ki rekòlte nan ranp yo (2) simen fèy ak branch ki rekòlte yo nan mitan ranp yo (3) mete fèy ak branch yo anba tè nan premye koup la, answit simen yo nan mitan ranp yo nan lòt koup yo. Twa fason sa yo te konbine ak twa dat koup ki fèt sou ranp lesena yo: (a) lè n'ap simen lòt kilti a, answit 30 jou apre (b) lè n'ap simen lòt kilti a, answit 40 jou apre (c) lè n'ap simen lòt kilti a, answit 30 ak 60 jou apre. Temwen yo te genyen misèk ladan yo.

Rezilta ki pi enpòtan:

Konparezon Misèk ak Ranp Lesena

- Nan premye lane etid la, mayi ki te simen nan mitan misèk yo bay plis randman pase mayi nan mitan ranp lesena yo. Nan dezièm lane a, misèk yo bay menm randman ak pi bon tretman nou te etidye a (twa koup ak itilizasyon fèy ak branch).
- Nan mitan misèk yo, randman mayi a te bese apre chak sezon. Nan mitan ranp yo, pou pi bon tretman nou te itilize a, randman mayi a pat janm bese sezon apre sezon.
- Kantite azòt fèy ak branch vèt lesena yo te pote te kont.

Jesyon Ranp

Jesyon ranp lesena yo enpòtan pou randman kilti ak randman ranp yo tou. Desen ki sou figi a montré efè jesyon an sou randman mayi ak pwodiksyon lesena nan katryèm sezon an.

- Lè nou retire fèy ak branch lesena ki rekolte nan jaden an, randman mayi a bese men pratik sa a pa twò change pwodiksyon lesena a.
- Mete fèy ak branch vèt lesena nou rekolte yo anba tè nan premye koup la bay menm randman mayi ak teknik simen fèy ak branch vèt nan mitan ranp yo.
- Lè nou fè twa (3) koup (lè n'ap simen, answit 30 ak 60 jou apre), nou jwen plis randman mayi pase lè nou fè de (2) koup.
- Lè nou fè twa (3) koup (lè n'ap simen, answit 30 ak 60 jou apre), lesena yo pwodwi mwens pase lè nou fè de (2) koup.
- Nou te jwen plis randmam lesena lè nou fè de (2) koup (lè n'ap simen ak 40 jou apre).

<u>Empòtans travay sa-a pou plantè yo</u>:

- Itilizasyon misèk pou konbat ewozyon pa pèmèt an menm tan bon jan pwodiksyon pou lontan.
- Itilizasyon fèy ak branch vèt lesena kòm manje bèt ap fè randman kilti yo bese si lòt teknik pa fèt pou ranplase matyè òganik yo.
- Aplikasyon fèy ak branch vèt lesena sou tè a oubyen mete yo anba tè ka kenbe randman kilti yo pou lontan
- Li nesesè pou plantè yo ta jwenn yon lòt mwayen pou bay bèt yo manje.

<u>Rekòmandasyon pou Pwojè PLUS</u>:

- Li nesesè pou pwojè PLUS kontinye ankouraje moun plante ak pranswen ranp vivan.
- PLUS dwe travay pou fè konprann pi byen enpòtans aplikasyon fèy ak branch lesena sou tè a genyen sou randman kilti yo.

- PLUS dwe travay pou fè konprann enpòtans dat koup ranp vivan yo genyen sou randman kilti.
- PLUS dwe ede chèche lòt fason pou bay bèt manje ki ta dwe sèvi kòm konpleman men ki pa la pou fè konpetisyon ak bezwen kilti yo.

Rekòmandasyon pou Rechèch kay peyizan ak M&E:

- Rezilta sa yo dwe konbine ak rezilta travay rechèch kay peyizan pou fè travay evalwasyon ekonomik ranp vivan yo pi konplè.
- Analiz fèy ak branch lesena yo nesesè pou byen estime kantite azòt chak kalite jesyon pote pou kilti a.
- Plis atansyon dwe bay sou jesyon ranp ak itilizasyon rekòt ranp yo nan kad etid M&E (swivi ak evalwasyon) kap fèt sou ranp vivan.
- Travay sa-a dwe kontinye pou wè efè jesyon an sou yon peryòd ki pi long.
- Lòt etid nesesè nan lòt zòn pou bon jan rekòmandasyon sou lè pou fè koup ranp la nan divès kondisyon lapli ak kalité tè ak sou lòt kilti tou.

INTRODUCTION

The traditional hillside farming systems practiced by small farmers in Haiti were characterized by rotations with mixed cropping followed by a fallow period to restore soil productivity. These systems had, over the years, ensured farmers a diversified output for household consumption and the satisfaction of primary needs.

During the last three decades, increasing population density and lack of more suitable land have increased the pressure on sloping hillsides. Fallow periods have been drastically reduced in most regions, or have disappeared altogether. In low input agriculture, long fallow periods serve to restore soil productivity and permit additional cropping. Continuous cropping results in a decline in organic matter, loss of soil fertility and a deterioration in soil structure, rendering it more vulnerable to soil erosion. On steep slopes, intensive cropping without appropriate soil conservation measures has resulted in high rates of erosion. Farmers are faced with a subsequent decrease in crop yields. New methods, capable of improving and maintaining soil productivity are needed to achieve sustainable crop production under more intensive cropping.

The use of hedgerows to reduce soil loss from cropped land is increasing in some regions, thanks largely to the efforts of the implementing organizations of the Productive Land Use Systems (PLUS) Project, formerly Agroforestry II (AF II), as well as other projects. Alley cropping, a refinement of the hedgerow system practiced in Haiti, has shown great promise in Africa and Asia as a viable technique to sustain crop production in hillside agriculture systems. For this reason, it was felt appropriate in 1990 to test alley cropping under Haitian conditions with the aim of providing low resource Haitian farmers with a means to sustain the productivity of their fields.

Experience with Alley cropping

Alley cropping or hedgerow intercropping is a system whereby annual crops are planted between rows of leguminous multipurpose trees, which are pruned during the cropping season and the prunings applied to the soil as mulch or incorporated as green manure (Kang *et al.*, 1984). During periods where no crop is grown, the trees are allowed to grow freely.

Benefits of alley cropping reported in the literature are reported in SECID/Auburn PLUS Report No. 6 (Shannon and Isaac, 1993). This technology has been shown to have the potential for sustaining soil productivity by maintaining soil organic matter, improving moisture retention, adding nitrogen, recycling other plant nutrients and reducing erosion (Kang *et al.*, 1984; Bannister and Nair, 1990; Farmer and Juo, 1990; Shannon *et al.*, 1994). The nitrogen contribution from the prunings to crops has been studied in recent years. Kang (1989), cited in Shannon *et al.* (1994), estimated the yearly N contributions by *Leucaena leucocephala* hedgerows to a crop in alley-cropping at 230 kg ha^{-1}, whereas Balasubramanian and Sekayange (1991) estimated the nitrogen supply from leucaena prunings at 120 Kg ha^{-1}. Availability of nitrogen from leucaena prunings to the current season's crop has been reported to range from as low as 3.2 % to as high as 65 % (Guevara, 1976, Brewbaker and Evensen, 1984, cited in Chirwa *et al.*, 1994; Mulongoy and van der Meersch, 1988).

The effects of alley cropping on increasing soil organic matter have been reported. As compared to a tree-less control plot, alley cropping plots had 80 % more soil organic matter after six years of cropping (Kang, 1992). Higher soil moisture content was observed in plots with *L. leucocephala* or *Flemingia macrophylla* hedgerows than in tree-less plots (Chirwa *et al.*, 1994).

Alley cropping has given encouraging results with a variety of crops. Maize yields (*Zea mays*) were higher with alley cropping using various hedgerow species than in the control plots which had no trees (Kang and Wilson, 1987; Balasubramanian and Sekayange, 1991; Shannon *et al.*, 1994). Results of long-term alley farming trials conducted in Nigeria have shown that by applying leucaena prunings, even without other

N application, maize yields can be maintained for many years at the reasonable level of approximately 2 tons ha^{-1} (Kang, 1992). The positive effects of alley cropping with various hedgerow species have also been reported on beans (*Phaseolus vulgaris*), sorghum (*Sorghum bicolor*) and yam (*Dioscorea alata*) (Balasubramanian and Sekayange, 1991; Chéry, 1990).

However, obtaining the full benefits of the alley cropping system depends on an appropriate design, successful hedgerow establishment and efficient management (Kang, 1992). Information in the literature on how to successfully manage hedgerows is limited. In a study conducted at Gandajika, Zaire, Shannon *et al.*, (1994) obtained a yield increase in maize in an alley cropping system where leucaena hedgerows were pruned two to three times at five-to-six week intervals during the season and the prunings applied as mulch to the soil. Dalland *et al.*, (1993) reported significant increases in maize yields when leucaena prunings were incorporated into ridges at 1 m spacing on which maize was sown. A second pruning was made forty five days later. Under semi-arid conditions, Tilander (1993) evaluated the effects of a combination of timing of application and dosage of *Azadirachta indica* and *Albizia lebbeck* leaf mulch on yields of sorghum (*S. bicolor*). Dosage had a significant influence on sorghum yields in all three years of the study whereas timing of application was significant in two consecutive years but the response was not consistent. In a review, Kang and Mulongoy (1992) attribute the low N use efficiency reported in several alley cropping trials to lack of synchronization between N release from the prunings and crop development.

In Haiti, hedgerow management has been left to the farmers. Under current practice, hedgerow prunings are not generally applied to the alleys. Soil retention, rather than soil fertility improvement is the primary goal. However, planting contour hedgerows permitted farmers in the Northwest to grow maize next to hedgerows in fields where they could previously only grow sorghum (Shannon and Isaac, 1993). Also, many farmers in the South region sow maize (*Z. mays*) in alley cropping with leucaena hedgerows that are pruned once during the cropping season (G. Brice, personal communication; Pierre *et al.*, forthcoming).

Information on hedgerow management requirements under Haitian conditions is lacking. Optimum management practices need to be worked out in order to make recommendations. Increased pruning frequency reduces hedgerow vigor but decreases competition with the crop. Prunings made late in the growing cycle of a crop are less likely to benefit the crop. The management strategy sought is one which 1.) maximizes biomass availability to the crop during the period in which it may benefit from nitrogen release through decomposition of prunings, 2.) minimizes competition with the crop during the vegetative and early reproductive stages of the crop, and 3.) favors optimum production of hedgerow biomass given these constraints. Since hedgerow growth varies greatly depending upon the environment in which it is grown, optimum pruning regimes must be determined with respect to specific environments.

The objective of this study is to determine the effect of different modes of utilization of prunings and to identify the optimum pruning regime in order to optimize crop yield under lowland conditions in Haiti.

MATERIALS AND METHODS

The study site was located at Bois Greffin, Pernier, approximately six miles east of Pétion Ville. The elevation is about 250 m and the mean annual temperature, 27.5° C. Annual rainfall recorded over a three-year-period averaged 1380 mm, distributed mainly between mid February and mid June and between September and November. This rainfall distribution pattern permitted two maize crops a year. The soil is a fine, mixed isohyperthermic Lithic Eutropept (Guthrie *et al.*, forthcoming). It is derived from limestone parent material, has a dark brown gravelly clay loam surface horizon with pH

= 8.0 over a dusky red clay B horizon. Depth to bedrock varies but is generally shallow. The soil profile studied was 40 cm deep. The site has a north-facing slope of 32 % with stone dry walls resulting in terraces of 18-25 % slopes. Based upon rainfall records, the site may be considered intermediate in terms of the range in rainfall conditions within which alley cropping is expected to be practiced in Haiti. Thus the Bois Greffin site may be considered representative of lowland conditions in Haiti, although the limited volume of soil for storage of moisture makes it behave more like a low rainfall site.

In previous years, maize (*Zea mays*), cassava (*Manihot esculenta*) and pigeon pea (*Cajanus cajan*) were planted in the first rainy season followed by carrots (*Daucus carota*) and sweet potato (*Ipomea batatas*) in the second season (Appendix Table A1). These were irrigated by ditch irrigation from a nearby stream. During the three years prior to establishing the trial, carrots and lima bean were planted in the second season following a grazed fallow in first season.

Site Preparation

Many scattered dry wall terraces were present in the field. The plots of 8 m perpendicular to the contour and 6.5 m along contour were laid out in March and April 1991 (Fig. A1). Care was taken to avoid outcroppings or very shallow soil particularly in the plot harvest areas. The upper limit of the plots was determined by the presence of a wall or outcropping. The lower limit was placed at least 1.5 m from the edge of the lower dry wall, if one was present. In replicates 1 and 2, the stone walls were removed but the soil that had built up behind the wall was left intact. In replicate 3, it was not possible to remove the wall from all plots. Where not enough space was available, the wall was displaced and soil was filled in behind the new wall. Where no wall previously existed, a wall was built but no fill was added.

In some places, large boulders were removed. In some plots, where bedrock within 10 cm of the surface could not be avoided, the bedrock was chipped away to allow at least 20 cm of soil.

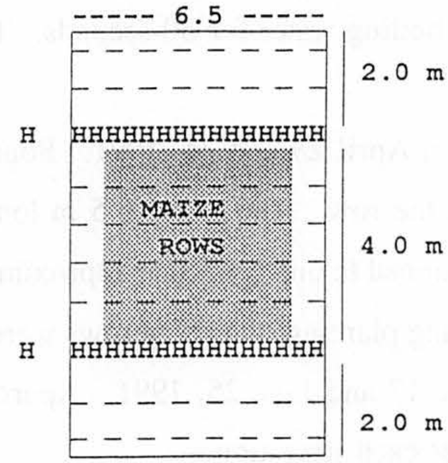
Experimental Design

Treatments are arranged as a 3 X 3 factorial with a control using a randomized complete block design. Three modes of utilization of hedgerow prunings were tested in all combinations with 3 hedgerow pruning regimes. The pruning utilization treatments were: (1) prunings removed, (2) prunings applied as mulch, and (3) prunings incorporated at each maize planting, with subsequent prunings applied as mulch. Mulching is the broadcasting of biomass on the soil surface whereas incorporation refers to working the fresh biomass into the upper few centimeters of soil by cultivation (MacLean, 1991). The three pruning regimes were: (a) pruning at time of maize planting and 30 days after planting (DAP), (b) at planting and 40 DAP and (c) at planting, 30 DAP and 60 DAP. A tenth treatment consisted of a dry wall as a control or standard for comparison. These ten treatments were replicated three times.

The plots, 6.5 m long X 8.0 m wide, consisted of four or five rows of maize (80 cm apart) between two leucaena hedgerows or two dry walls, respectively. Dry walls as well as leucaena hedgerows were spaced 4 m apart (Figures 1 and A1). The maize harvest area was 4.5 m by 4 m.

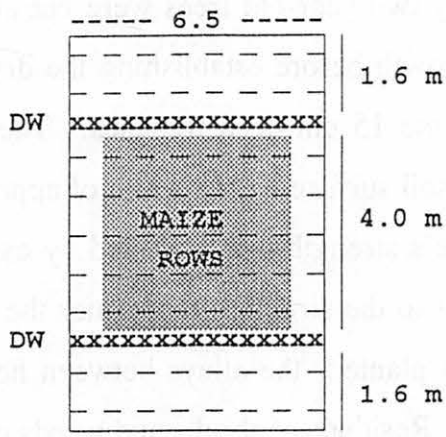
Hedgerow and Wall Establishment

The locations of two hedgerows were marked out per plot. A line level was used to place the hedgerows along the contour, thus determining at the same time the upper and lower borders of the plots. The hedgerows were located 2 m from the upper and lower boundary of the plot, leaving an alley of 4 m in the center of the plot. Land preparation was conducted in the first two weeks of April 1991. A width of about 30 cm was deep hoed with a pick and leveled with a rake.



(H = HEDGEROW)

(Area Shaded = Harvested Plot)



(DW = Dry Wall)

Figure 1. Treatment layout in Agroforestry Adaptive Trial 2.

Leucaena leucocephala variety K8 was used as the hedgerows species. The seed was collected from the Operation Double Harvest site at Cazeau. Seed pretreatment consisted of immersion in boiling water for 30 seconds. The hot water was drained off and cold water applied.

Seeding was done on April 23 and 24, 1991. Four seeds were planted per hill, spaced 0.1 m apart within the row. The rows, 6.5 m long, were spaced 4 m apart on contour. Seedlings were thinned to one per hill at approximately six weeks after planting. Because of drought following planting, the hedgerows were watered with a watering can or bucket on May 17, June 17 and June 25, 1991. Approximately 2.3 l of water were applied per meter of row at each irrigation.

The stone dry walls were constructed in January 1993, two months before planting maize. All plots were initially sown to leucaena, with the intention that in the control plots the seedlings would be uprooted and walls constructed in their place. Because of suspension of the project for one year, the trees had grown to 3-4 m height before they were removed. The nearly two-year-old trees were cut at approximately 15 cm below the ground to prevent regrowth before establishing the dry walls. Foundations for the walls were constructed in the 15 cm deep trenches. The walls were constructed to a height of 20 cm above the soil surface with a width of approximately 30 cm. No mortar was used, and the structure's strength was achieved by careful positioning of the rocks and giving a slight back-tilt to the structure to counter the effects of gravity.

Until the maize was planted, the alleys between hedgerows and walls were left without disturbing the soil. Residues of shrubs and weeds removed during weeding were left on the soil surface.

Hedgerow Management

The hedgerows were approximately two years old at the start of the experiment. Hedgerows were pruned to a height of 50 cm, beginning twenty-two days before the first maize seeding. This first pruning took place between March 1 and March 11, 1993, when hedgerows were approximately 4 m height. In subsequent seasons (second, third and fourth cropping seasons), the first pruning was done nine, five and three days prior to planting maize, respectively. According to the treatment, one or two subsequent prunings were made during the cropping season.

Following pruning, large stems were placed next to the hedgerows on the uphill side of the hedgerows to increase the barrier effect. This is in keeping with farmer practice in Haiti. However, in plots where prunings were removed branches and large stems were also removed except in some cases where branches are used to fill in gaps to prevent gully formation. Leaves and small stems were either incorporated in bands next to the maize seed, spread over the surface of the alleys or removed from the plots, according to the treatment.

Maize Crop

Maize was first seeded in the alleys between hedgerows or dry walls on March 23, 1993. Maize was planted in subsequent seasons on August 24, 1993, March 9 and August 26, 1994. Two maize crops a year were grown. Maize was planted in March and harvested in June or July and again in late August and harvested in December (periods of first and second rainy seasons), referred to as season A and Season B, respectively.

One month prior to the initial planting, the first soil preparation was done with hand tools, hoe and pick, and the plant residues left on the soil surface. In subsequent cropping seasons, the first soil preparation took place approximately fifteen days before maize planting. A few days before seeding of maize, a second soil preparation with a hoe was done. In alley cropping plots, harvested leaves and green stems, referred to as prunings, were returned to the soil as mulch, incorporated or removed, according to the treatment. In Seasons 2-4, residue from the previous maize crop was incorporated into the soil with the first soil preparation.

A local population of maize was planted in hills 40 cm apart in rows spaced at 80 cm. Three seeds were planted per hill. Fifteen days after planting, the maize was thinned to one plant per hill. Four rows of maize were planted between two hedgerows and five were planted between dry walls in control plots (Fig. 1). A first weeding took place thirty days after planting and a second approximately three weeks later. The maize was grown during the first and second rainy seasons for two consecutive years (four cropping seasons). Maize was harvested at 113 and 120 days after planting, during the first and third cropping seasons, respectively, and at 112 and 130 DAP in the second and fourth seasons, respectively.

Observations

During the cropping season, maize plants were counted after thinning and at harvest. Data recorded at harvest were: grain yield in ton/ha calculated at 13% moisture, plants lodged determined as percent of lodging in a plot, number of ears harvested, number of fertile maize plants, maize height, fresh weight of ears and percent moisture of harvested grain determined by means of a grain moisture tester.

At harvest of hedgerows, prunings were divided into leaves, green stems < 1 cm in diameter, stems 1-5 cm in diameter, stems > 5 cm in diameter and pods. Fresh weight of each component was determined separately in the field. Samples of fresh biomass of each component were oven-dried at 71.0^{0} C for dry matter determination.

Analysis of variance was carried out for all variables each cropping season. The Statistical Analysis System (SAS), was used for all statistical analyses. Among treatments, orthogonal or balanced comparisons were determined using the contrast statements in the model.

RESULTS

RAINFALL CONDITIONS

Total rainfall recorded over the cropping season periods, beginning approximately fifteen days before maize planting, was 558.4 mm and 766.4 mm during the first rainy seasons (Fig. 2A), and, 493.8 mm and 797.6 mm during the second rainy seasons (Fig. 2B). Inadequate rainfall distribution in each season, gave rise to drought stress at various stages of crop development. In the first cropping season (first rainy season, 1993), drought stress occurred during almost the entire vegetative stage and during the grain-filling period. Phosphorus deficiency was observed in almost all plots. In the second cropping season (second rainy season, 1993), drought stress occurred at the start of the silking period. In the third season (first rainy season, 1994), drought stress occurred soon after flowering and continued until maturity. During the fourth cropping season (second rainy season, 1994), drought stress occurred during part of vegetative stage and again during the final stage of grain filling (Fig. 2A and Fig. 2B).

MAIZE CROP

<u>Grain Yield</u>

Effect of Pruning Use

In all four seasons, application of the leucaena leaves and green stems either as mulch or with incorporation of the first pruning resulted in significantly higher maize yields than removal of prunings (Table 1). There were no significant differences in maize yields between incorporation of first pruning and application as mulch during any of the four seasons. The effect of pruning use was most pronounced in the fourth season, when the application of prunings to the soil as mulch or incorporation of first pruning resulted in 98 % and 91 % higher maize yield, respectively, than where the prunings were

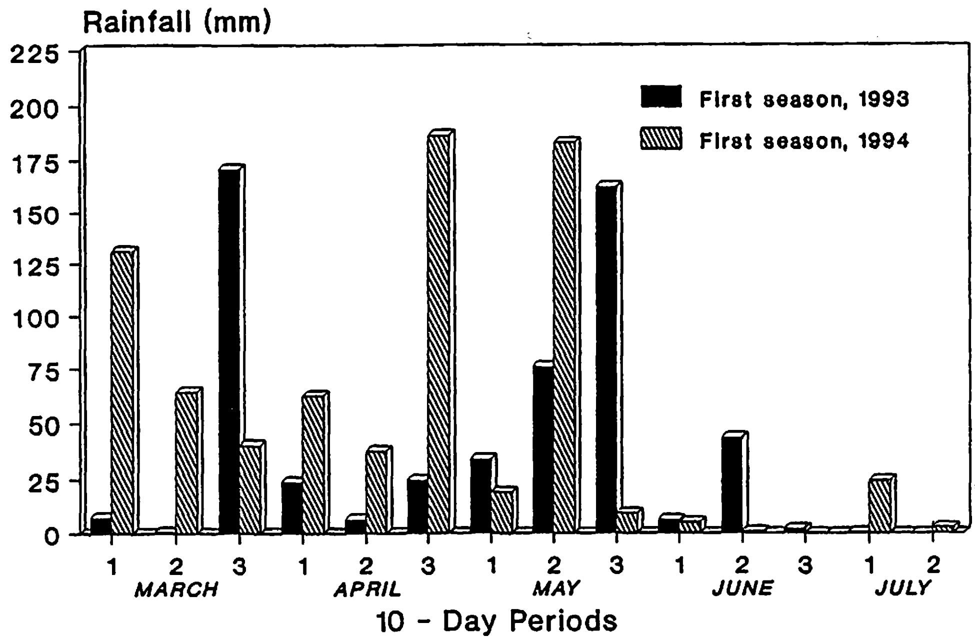


Figure 2A. Rainfall during the first rainy seasons.

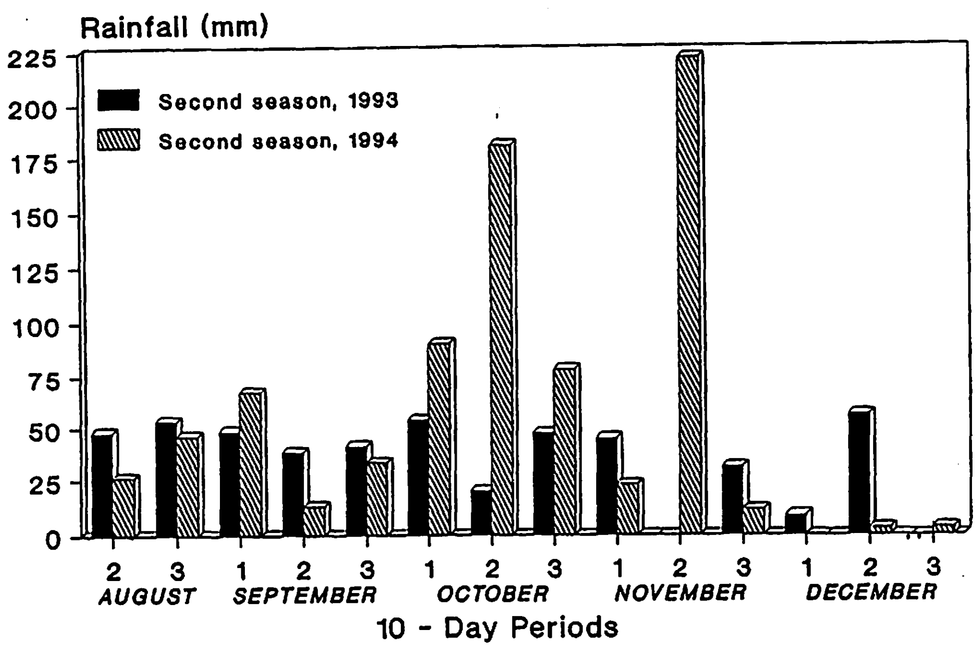


Figure 2B. Rainfall during the second rainy seasons.

Table 1. Maize grain yield at 13 % moisture in the first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

Factors	Cropping Seasons[†] 93-A	93-B	94-A	94-B
	t/ha			
Pruning Utilization				
Removed	0.61	0.57	0.52	0.43
Mulch	0.87	0.69	0.79	0.85
Incorporated/Mulch[‡]	0.86	0.74	0.83	0.82
Orthogonal Comparisons				
Removed vs Applied	**	*	***	***
Mulch vs Incorp.	ns	ns	ns	ns
Pruning Regime				
Planting + 30 DAP[§]	0.68	0.54	0.60	0.62
Planting + 40 DAP	0.60	0.65	0.60	0.60
Planting + 30+60 DAP	1.05	0.80	0.94	0.89
Orthogonal Comparisons				
3 vs 2 Prunings	***	***	***	***
30 vs 40 DAP	ns	ns	ns	ns

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Pruning incorporated at planting, mulch thereafter; §/ DAP = Days after planting.

ns, *, **, *** = Not significant, significant at the 5 %, 1 % and 0.5 % levels of probability, respectively.

removed (Figure 3).

Effect of Timing of Prunings

Prunings made on the leucaena hedgerow three times (0, 30 and 60 DAP) during the growing season resulted in significantly higher maize yields in all seasons than pruning twice (Table 1). There were no significant differences between the two-pruning regimes in any of the four seasons. The effect of pruning regime was slightly more pronounced in the first and third cropping seasons, when the three-pruning regime resulted in 64 % and 57 % higher maize yields, respectively, than the two cut regimes (Figure 4).

Stone Walls vrs. Hedgerows

During the first three seasons, highest maize yields were obtained from the control plots (stone dry wall) followed by the treatments with three prunings where the prunings were applied as mulch or incorporated at first pruning and then applied as mulch (Table 2). In the third and fourth seasons, however, there were no significant differences among those three treatments. In the fourth season, treatments with three prunings where the prunings were applied to the soil produced more than the control treatment with 1.08 and 1.02 v.s. 0.93 t ha^{-1}, respectively (Table 2), but these differences were not statistically significant. Compared to the highest yielding alley cropping plots, maize yields in control plots were 37 % higher in the first season, but 16 % less than in the same alley cropping plots in the fourth season.

Comparisons among alley cropping treatments

Across seasons, highest maize yields were obtained in the Season A (first rainy season) with the three-pruning regime with prunings applied to the soil as mulch or incorporated at first pruning and then applied as mulch (Table 2). The least productive

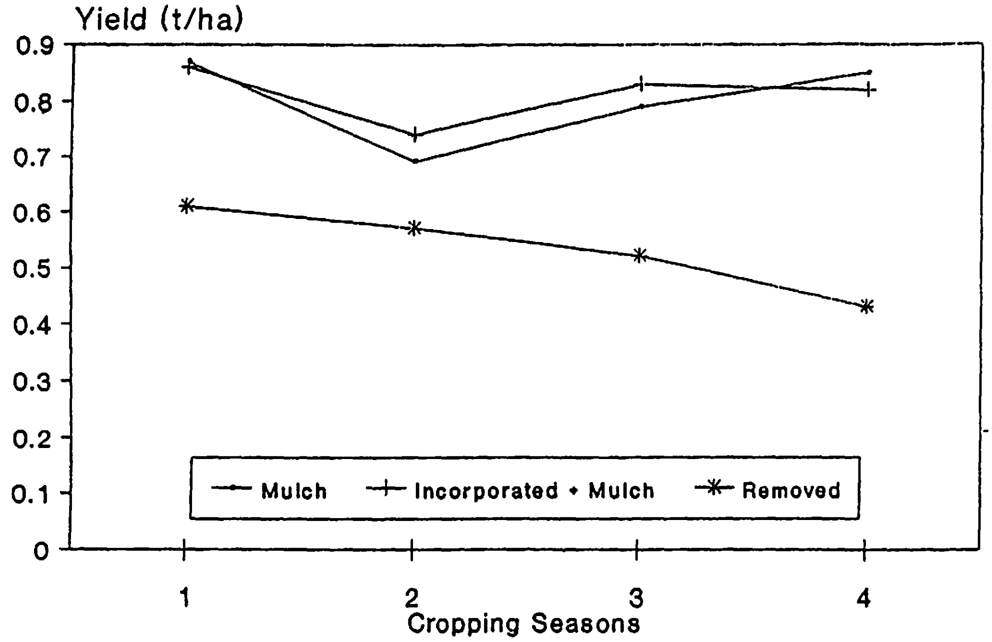


Figure 3. Effect of pruning utilization on maize yields in first four cropping seasons.

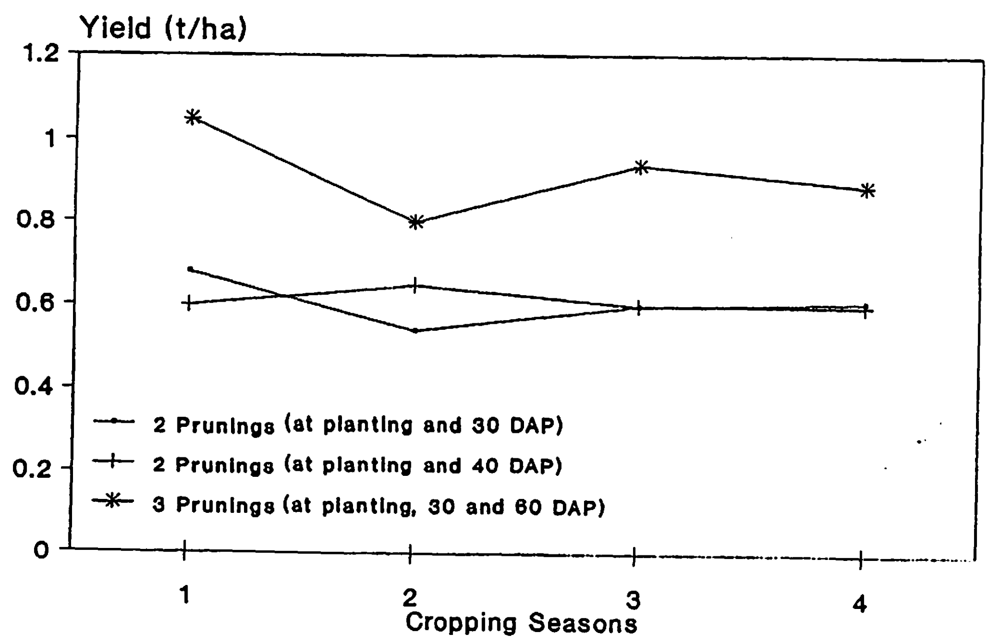


Figure 4. Effect of pruning regime on maize yields in first four cropping seasons.

Table 2. Maize grain yield at 13 % moisture in first four cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Cropping Seasons[†] 93-A	93-B	94-A	94-B
	t/ha			
Removed				
Planting + 30 DAP[‡]	0.29	0.40	0.23	0.40
Planting + 40 DAP	0.74	0.65	0.65	0.34
Planting + 30+60 DAP	0.79	0.66	0.68	0.56
Mulch				
Planting + 30 DAP	0.94	0.59	0.78	0.74
Planting + 40 DAP	0.44	0.60	0.44	0.72
Planting + 30+60 DAP	1.22	0.87	1.15	1.08
Incorporated/Mulch[§]				
Planting + 30 DAP	0.82	0.64	0.79	0.71
Planting + 40 DAP	0.62	0.70	0.70	0.74
Planting + 30+60 DAP	1.13	0.87	1.00	1.02
Control (Dry Wall)	1.67	1.13	1.23	0.93
Significance (F test)	***	***	***	***
LSD $_{0.05}$	0.35	0.23	0.35	0.33
CV %	23.25	18.60	26.69	26.61

[†/] 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.
[‡/] DAP = Days after planting; [§/] Pruning incorporated at planting, mulch thereafter.
*** = Significant at 0.5 % level of probability.

treatment was the treatment of two prunings with the prunings removed at 0 and 30 DAP. During the first and third seasons, maize yields were also very low (0.44 t ha^{-1}) in the treatment where pruning was done at 0 and 40 DAP and the prunings were applied as mulch (Table 2). Low yields in this treatment may be attributed to several factors. During the first growing season, phosphorus deficiency was observed earlier and to a greater extent in these plots than in other treatments. Of major importance is the presence of bedrock near to the soil surface in replication 2 of this treatment. It is likely that the effects of dry weather (Fig. 2A) and shallow soil combined to reduce the number of fertile plants and consequently, lower yield.

Time Trends

Although Season A seems to be more favorable for maize than the Season B, the trend over time has been a yield decline in the control plots (Figure 5).

Where prunings were removed from plots, there has also been a trend toward decreased maize yields (Table 1). Where they were applied to the soil, yields have tended to be stable over the seasons.

Interactions

Statistically significant interactions between pruning utilization and pruning regime were obtained with respect to maize grain yields during the first ($P < 0.005$) and third ($P < 0.01$) cropping seasons, respectively. When prunings were removed, cutting at 0 and 40 DAP gave higher yields than cutting at 0 and 30 DAP (Table 2), whereas when prunings were applied, the reverse was true. In season 2, cutting at 40 DAP was consistently better than cutting at 30 DAP, while in Season 4, there was little difference between 30 and 40 DAP cuts, and hence there were no interactions for these harvest dates.

The three-pruning regime with application of leucaena prunings to the soil

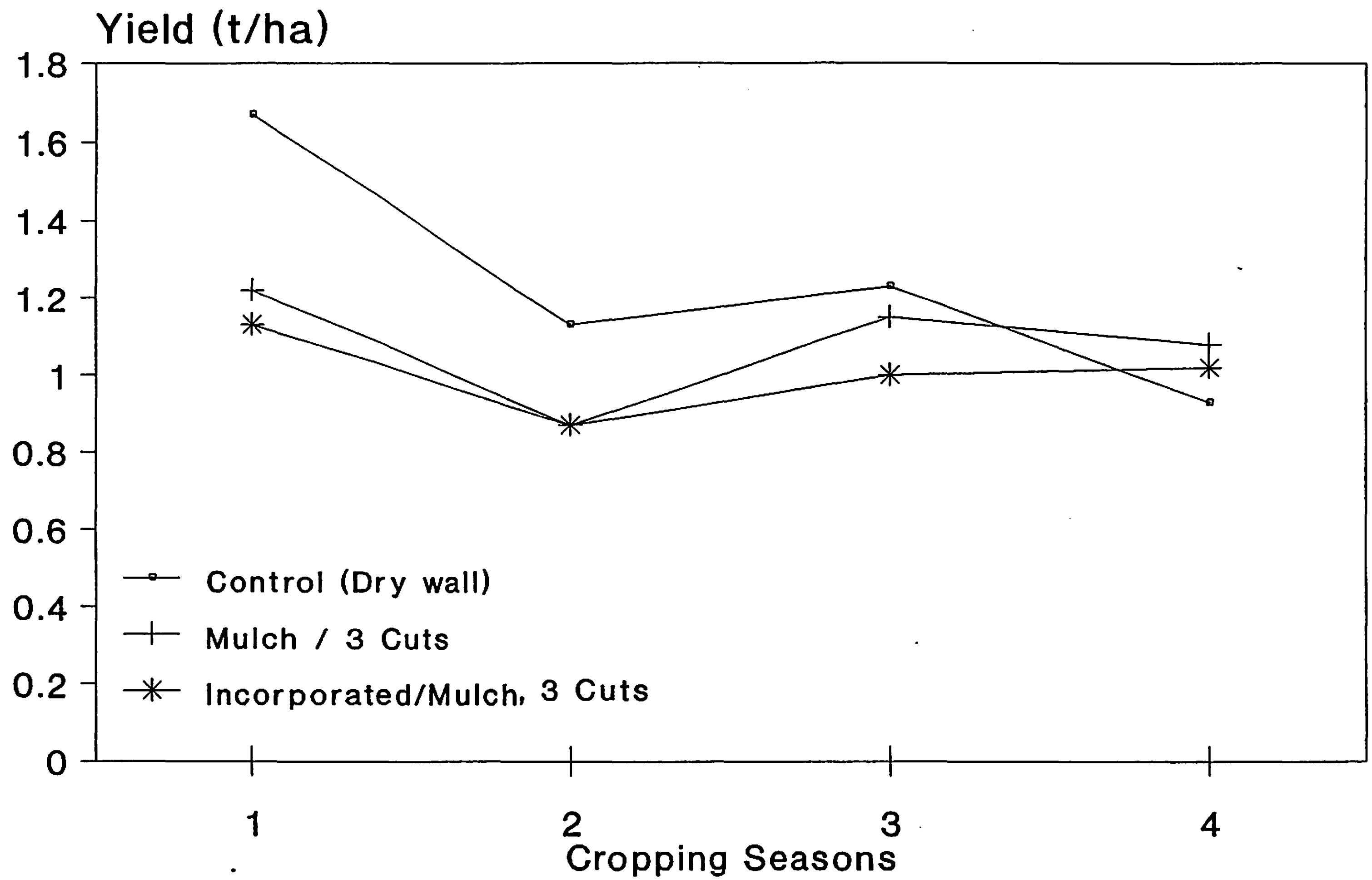


Figure 5. Effect of best hedgerow treatments on maize yields in first four seasons compared to stone wall.

consistently resulted in higher maize yields than other combinations of hedgerow management (Table 2). Application of prunings as mulch gave higher yields under a three-pruning regime than the incorporation of first pruning, except for the second season. However, the reverse was often the case when two cuts were practiced, i.e. greater yields were often obtained when the first pruning was incorporated into the soil (Table 2).

Other Measurements on Maize

Additional measurements taken on the maize crop provide additional insights and support to the yield data presented above. Among these, fresh ear weight, number of ears harvested, percent fertile plants, percent lodged plants, percent moisture content in grain at harvest and maize stand counts after thinning and at harvest are presented in Appendix II.

HEDGEROW BIOMASS PRODUCTION

Results presented herein for each component are the total production in the two or three prunings done during each cropping season. Biomass fresh weight in all four seasons, wood and pod biomass production in the first season and biomass production in each individual pruning are presented in Appendix Tables A10 - A16.

Total and Leaf Biomass

Leaves are the most important hedgerow biomass component for alley cropping. They decompose rapidly and the nutrients they contain are most readily available to the crop. Total biomass is an indication of the overall productivity of the hedgerows.

Effect of Utilization of Prunings

Mode of utilization of prunings did not have a significant effect on total and leaf

Table 3. Total and leaf dry weight biomass harvested from hedgerows in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

Factors	Total/Seasons[†]				Leaf/Seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Pruning Utilization								
Removed	15.13	3.72	2.27	2.25	2.90	1.91	1.37	1.25
Mulch	15.83	3.82	2.42	2.44	2.94	1.90	1.34	1.35
Incorporated/Mulch[‡]	15.62	3.96	2.56	2.50	2.97	2.02	1.44	1.38
Orthogonal Comparisons								
Removed vs Applied	ns	ns	ns	ns	ns	ns	ns	ns
Mulch vs Incorp.	ns	ns	ns	ns	ns	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[§]	14.55	4.06	2.53	2.20	2.67	1.88	1.32	1.12
Planting + 40 DAP	16.53	4.44	2.86	3.16	3.09	2.15	1.51	1.63
Planting + 30+60 DAP	15.49	3.01	1.87	1.83	3.06	1.79	1.31	1.23
Orthogonal Comparisons								
3 vs 2 Prunings	ns	***	***	***	ns	*	ns	ns
30 vs 40 DAP	ns	ns	ns	***	ns	*	*	***

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Pruning incorporated at planting, mulch thereafter; §/ DAP = Days after planting.

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

dry weight biomass in any of the four seasons (Table 3). However, except for the first season, incorporation of the first pruning into the soil ranked highest in total and leaf biomass produced.

Effect of Pruning Regime

Pruning regime significantly affected total and leaf dry weight biomass during the last three cropping seasons (Table 3). The three-pruning regime produced less total biomass than the two-pruning regimes in all but the first season. In all seasons, pruning at 0 and 40 DAP ranked highest in total and leaf biomass production. In terms of statistical significance, pruning at 40 days was superior to pruning at 30 days in the fourth season for total biomass and during the last three seasons for leaf biomass (Table 3). Moisture content of the prunings (not shown) was also affected by timing of prunings, but interpretation is more complex.

Time Trends

Highest total biomass was produced during the first season (Table A13). These yields were high because the hedgerows were approximately two years old and had not previously been pruned. Ignoring the first season, a general decline in total and leaf biomass yield seems to have occurred over the seasons (Table 3). However, in the fourth season, a slight increase in total and leaf biomass (compared to the third season) appeared to have occurred when the pruning was done at 0 and 40 DAP and the prunings were applied to the soil (Table 4).

Cumulative leaf dry weight biomass production presented in Figures 6 and 7 gave an important overview for hedgerow productivity. Incorporation of first pruning appears to have produced highest cumulative leaf biomass (Fig. 6) while pruning twice at 0 and 40 DAP produced significantly more cumulative leaf dry matter than other pruning regimes from the second season onward (Fig. 7).

Table 4. Total and leaf dry weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial II.

	Total/Seasons[†]				Leaf/Seasons			
Treatments	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Removed								
Planting + 30 DAP[‡]	13.01	3.62	2.18	1.92	2.52	1.77	1.19	1.02
Planting + 40 DAP	18.31	4.55	2.89	3.08	3.27	2.16	1.65	1.55
Planting + 30+60 DAP	14.07	3.00	1.74	1.75	2.91	1.79	1.26	1.18
Mulch								
Planting + 30 DAP	16.86	4.29	2.81	2.54	2.94	1.92	1.39	1.25
Planting + 40 DAP	14.55	4.15	2.58	2.94	2.78	2.02	1.34	1.59
Planting + 30+60 DAP	16.07	3.02	1.87	1.84	3.09	1.75	1.29	1.21
Incorporated/Mulch[§]								
Planting + 30 DAP	13.79	4.26	2.59	2.15	2.53	1.96	1.39	1.09
Planting + 40 DAP	16.74	4.61	3.09	3.46	3.21	2.28	1.55	1.76
Planting + 30+60 DAP	16.34	3.01	1.99	1.90	3.17	1.81	1.40	1.28
Significance (F test)	ns	*	***	***	ns	ns	*	*
LSD $_{0.05}$	4.88	1.09	0.65	0.72	0.94	0.43	0.26	0.40
CV %	18.17	16.41	15.58	17.44	18.60	12.77	11.00	17.39

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ DAP = Days after planting; §/ Pruning incorporated at planting, mulch thereafter.

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

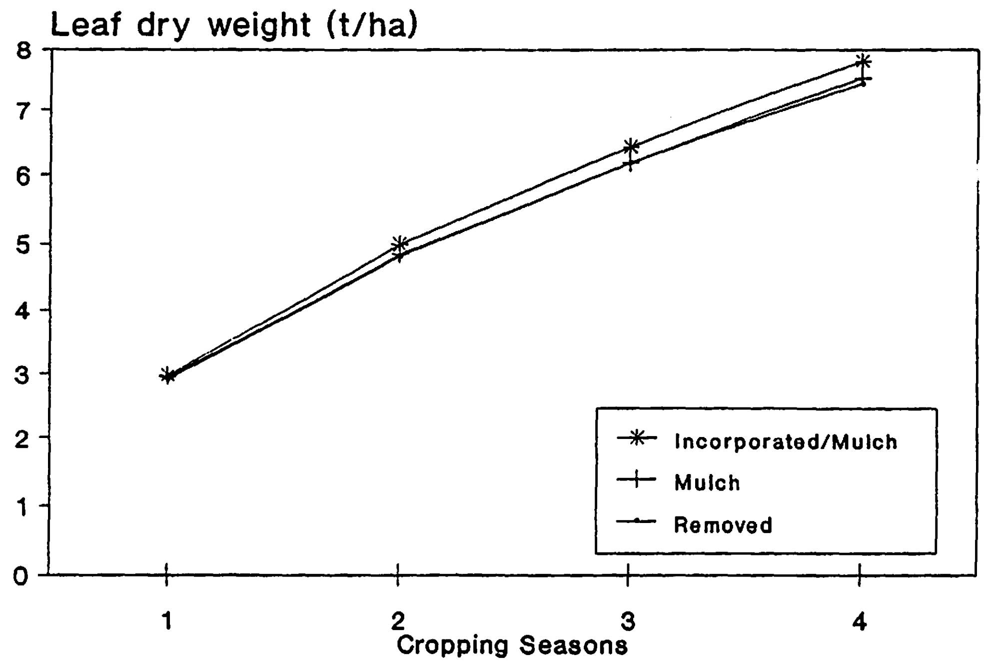


Figure 6. Effect of utilization of prunings on cumulative leaf dry weight biomass in first four seasons.

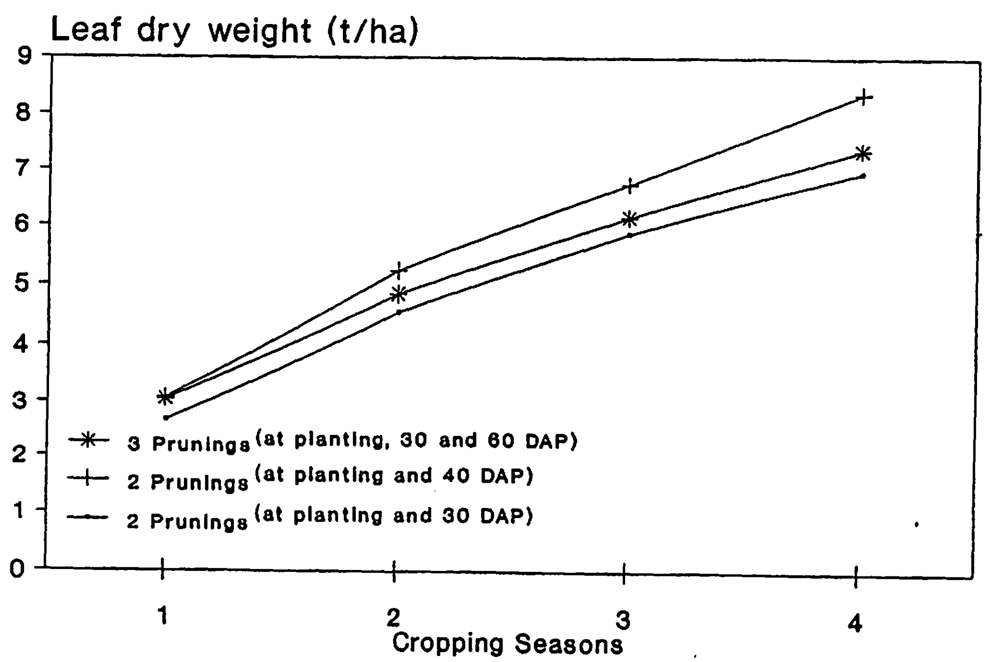


Figure 7. Effect of pruning regime on cumulative leaf dry weight biomass production in first four seasons.

Comparisons among treatments

During the first season, there were no significant differences among the treatments for total and leaf biomass (Tables 3 and 4). Pruning twice at 0 and 40 DAP with incorporation of first pruning ranked highest in total biomass during the last three seasons and was significantly more productive than other pruning regimes in the last season (Table 4). Irrespective of utilization of prunings, the three-pruning regime produced less total biomass in the last three cropping seasons, the treatment in which prunings were removed being the lowest.

The highest ranking treatment in terms of biomass production after the first season was that with pruning at 0 and 40 DAP with incorporation of the first pruning (Table 4). It consistently, but not significantly produced more leaves than pruning with mulching at 0 and 40 DAP. Over the four seasons, treatments with prunings at planting and 30 DAP and with prunings removed from the plots were the least productive.

Total and leaf fresh weight biomass are presented in Appendix Table A10 for further reference.

Interactions

For leaf and total biomass production, there were no significant interactions between pruning utilization and pruning regime. However, total dry weight appeared to be more affected by number of prunings (three vrs. two) whereas leaf dry matter production appeared to be more affected by timing of pruning (30 vrs. 40 DAP for two-pruning regime) (Table 3).

Branch and Stem Biomass

Of the components of biomass, small green stems, referred to here as branches, are secondary in value as a nutrient source, being slower in decomposition than leaves and lower in nitrogen (N). The larger woody stems decompose slowly, and because of a high proportion of carbon to N, tie up N, making it less available to plants. These stems have value in reinforcing the hedgerows as barriers to erosion and as secondary products, such as fuel or stakes.

Effect of Utilization of Prunings and Pruning Regime

The mode of utilization of prunings did not affect the production of branches and stems biomass during the four cropping seasons (Table 5). With respect to pruning regime, pruning at 0 and 40 DAP produced the most branch and stem biomass in all four seasons (Table 5). However, for branch biomass, this production was not statistically different from that of the other two-pruning regime during the second and third season. For stems, this regime was not different from pruning at 0 and 30 DAP except during the last season. The three-pruning regime was significantly less productive than the two-pruning regimes in both branch and stem biomass during the last three seasons.

Comparisons among treatments

During the first season, pruning at 0 and 40 DAP with prunings removed produced significantly more branches than any other treatment (Table 6). During the last two seasons, pruning at 0 and 40 DAP, with incorporation of first pruning, ranked higher than other treatments, although it did not differ significantly from removal or mulching at 0 and 40 DAP.

Statistically similar amounts of stem biomass were produced in the first season (Table 6). In the last season, pruning at 0 and 40 DAP, with incorporation of first pruning, produced more stem biomass than all other treatments. The three-pruning regime produced significantly less stem biomass than the two-pruning regimes.

Interactions

Significant interactions ($P < 0.005$) for branch biomass were obtained between

Table 5. Branch and stem dry weight biomass harvested from hedgerows in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

	Branches/Seasons[†]				Stems[‡]/Seasons			
Factors	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Pruning Utilization								
Removed	2.26	1.29	0.69	0.84	9.46	0.53	0.21	0.16
Mulch	2.15	1.29	0.77	0.87	10.41	0.63	0.30	0.22
Incorporated/Mulch[§]	2.20	1.35	0.78	0.89	9.93	0.60	0.33	0.24
Orthogonal Comparisons								
Removed vs Applied	ns	ns	ns	ns	ns	ns	ns	ns
Mulch vs Incorp.	ns	ns	ns	ns	ns	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[¶]	1.97	1.40	0.82	0.87	9.47	0.78	0.37	0.21
Planting + 40 DAP	2.34	1.48	0.92	1.16	10.53	0.81	0.42	0.37
Planting + 30+60 DAP	2.30	1.05	0.50	0.56	9.80	0.17	0.05	0.05
Orthogonal Comparisons								
3 vs 2 Prunings	ns	***	***	***	ns	***	***	***
30 vs 40 DAP	***	ns	ns	***	ns	ns	ns	***

†/ Branches = Green stems < 1 cm; 93-A = First rainy season, 24 March -15 July, 1993; 93-B= 2nd rainy season, 25 Aug.-15 Dec. 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Stems 1-5 cm (diameter); §/ DAP = Days after planting; ¶/ Pruning incorporated at planting, mulch thereafter.

ns, *** = Not significant, significant at the 0.5 % level of probability, respectively.

Table 6. Branch and stem dry weight biomass harvested from hedgerows in first four cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Branches/Seasons[†]				Stems[‡]/Seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Removed								
Planting + 30 DAP[§]	1.87	1.29	0.69	0.77	8.07	0.56	0.29	0.13
Planting + 40 DAP	2.76	1.52	0.94	1.23	11.64	0.88	0.30	0.30
Planting + 30+60 DAP	2.15	1.07	0.45	0.51	8.68	0.14	0.03	0.06
Mulch								
Planting + 30 DAP	2.18	1.41	0.91	0.98	11.23	0.97	0.49	0.31
Planting + 40 DAP	1.94	1.41	0.84	1.02	9.53	0.72	0.39	0.33
Planting + 30+60 DAP	2.33	1.05	0.55	0.60	10.46	0.21	0.03	0.03
Incorporated/Mulch[¶]								
Planting + 30 DAP	1.87	1.50	0.86	0.87	9.10	0.80	0.34	0.18
Planting + 40 DAP	2.31	1.50	0.97	1.24	10.41	0.83	0.57	0.47
Planting + 30+60 DAP	2.41	1.04	0.51	0.57	10.27	0.16	0.08	0.06
Significance (F test)	***	*	***	***	ns	***	***	***
$LSD_{0.05}$	0.33	0.30	0.26	0.23	3.48	0.42	0.24	0.15
CV %	8.68	13.39	19.82	15.64	20.24	41.39	49.38	41.48

†/ Branches = Green stems < 1 cm; 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.
‡/ Stems 1-5 cm (diameter); §/ DAP = Days after planting; ¶/ Pruning incorporated at planting, mulch thereafter.
ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

mode of utilization of prunings and pruning regime during the first season while there was no interaction between those two factors in other seasons.

Branch and stem fresh weight biomass and wood and pod biomass production in the first season are presented in Appendix Tables A11 and A12, respectively, for further reference.

DISCUSSION

MAIZE CROP

Pruning Utilization

The beneficial effect of applying the leucaena prunings to maize was evident from the first cropping season. On the average, over the seasons, maize yielded from 43 % (first season) to 98 % (fourth season) more in plots where prunings were applied as mulch and from 41 % to 91 % higher in plots where the first pruning was incorporated into the soil compared with plots where the prunings had been removed from the plots, respectively (Table 1 and Fig. 3). Application of prunings increased maize height, number of ears harvested, % fertile plants and decreased stand loss (Appendix II). These results are in accordance with Mulongoy and Van der Meersch (1988) who reported that the application of leucaena prunings increased grain yields of sole maize by 38 % and the maize yield in the alley-cropped plots by 104 %, compared with yields in the corresponding plots where prunings were not applied.

The combined dry weight of leaves and green stems applied as mulch or with first pruning incorporated and subsequent prunings applied as mulch were estimated at 8.28 and 8.54 t ha^{-1}, respectively, during the first year of the study, and 4.33 and 4.49 t ha^{-1} during the second year (Tables 3 and 5). Estimates of N concentration in prunings in the literature vary depending on age of prunings and material included in the determination: Balasubramanian and Sekayange (1991), 2.45 % in leaves, 0.8 % in wood; Kang (1993,) 3.33 % in leaves and twigs; Wilson *et al.* (1986), 4.33 % in unspecified prunings; Duguma *et al.* (1988), 4.47 and 4.68 % in leaves and green stems when cut at 50 cm height in 1-month and 3-month cycles, respectively. Balasubramanian and Sekayange grew leucaena under unfavorable low rainfall conditions favoring lignification of tissues. Based on values from Kang (1993) and Duguma *et al.* (1988) the leucaena prunings could have supplied around 276-391 Kg N ha^{-1} in the first two cropping seasons and about 144-205 Kg N ha^{-1} during the second two seasons. This is a substantial amount of N fertilizer.

The enormous reduction in maize yields from alley cropping plots where the prunings were removed in comparison with other alley cropping treatments, especially during the last two seasons, could be the result of competition for nutrients and water between the maize and the hedgerow trees. In the other alley cropping treatments, the effect of competition was probably less, due to the application of prunings which provide nitrogen to the associated maize crop and possibly improves soil moisture retention. These results demonstrate that, in an alley cropping system, if the prunings are used for animal feed and not applied to the soil, the yield of the associated crop may be consistently reduced.

The method of biomass application has been reported to influence the effects of tree roots on crops by affecting the efficiency of nutrient utilization by the crops and eventually the growth and distribution of roots in the soil (Kang and Mulongoy, 1992). Management practices such as incorporation of first pruning into the soil, have been reported to increase the efficiency with which N is transferred from prunings to the associated crop (Read *et al.*, 1985; Wilson *et al.*, 1986). In contrast to the latter reports, in our trial, the method of biomass application, either as mulch or with incorporation of the first pruning, did not result in significantly different maize yields (Table 1, Fig. 3).

Our results are comparable with those reported by Schroth *et al.* (1986).

Pruning Frequency

The three-pruning regime resulted in significantly higher maize yields in all four seasons compared to the two-pruning regimes (Table 1 and Fig. 4). Although the leaf and green stem biomass production under the three-pruning regime was lower than that of the two-pruning regimes during the last three cropping seasons (Tables 3 and 5), the three-pruning regime seems to have more effectively reduced competition from the hedgerows on the maize. A more intensive competition for light and possibly for water, especially during the later development stages of maize, may be responsible for low yields in plots where two prunings were made during the growing season. Similar results have been reported by Duguma *et al.* (1988), who observed higher maize yields with increasing pruning frequency. Also, Shannon *et al.* (1994), in order to reduce competition between hedgerows and maize, reduced the interval between prunings after the second cropping season. This observation implies that even when sufficient mulch is applied, if the maize is shaded by the hedgerow during part of its development, yield may be reduced.

Drought led to more sterile plants with two prunings than with three and the maize was often stunted. In the fourth season, 100 % sterility was observed in the third replication of the treatment with two prunings at 0 and 40 DAP where the prunings were removed. Drought in this case was compounded by nutrient stress brought about by removal of biomass from the plots.

Alley Cropping Compared to the Stone Wall Control

The maize grain production for the control treatment was clearly superior to all the other treatments during the first two cropping seasons. This can be attributed in part to a 20 % higher maize population in the control plots. In the third and fourth seasons, the yield of the control treatment did not differ significantly from that of the best alley cropping treatments (Table 2 and Fig. 5), and on a per row basis was inferior to these treatments.

The superior performance of the control treatment in the first two seasons, may also be attributed in part to residual effects. Two years prior to planting maize, the entire trial area was planted with leucaena hedgerows. In the control plots, the hedgerows were removed and stone dry walls constructed in their place two months prior to the first season maize planting. It is likely that the decomposing roots of leucaena trees, almost two years old, released nutrients which increased yields in the control plots during the first two seasons.

On the other hand, the moisture stress during the vegetative stage and at the start of the silking period during the first and second cropping seasons (i.e first and second rainy seasons of the first year of the trial, Figures 2A and 2B) would have intensified competition between the hedgerows and the maize in alley plots. In a study conducted during a two-year-period, Hulugalle and Ndi (1993) reported that highest maize cob yield occurred with no-tillage alone compared to maize crop under the system no-tillage combined with alley cropping. Shannon *et al.* (1994) reported 24 % lower maize yields in alley cropping plots compared to the control in the first year of their trial. By the third season, nutrients removed in harvest products are probably responsible for yield losses observed in control treatments, while nutrients were being replaced in the best hedgerow treatments.

Comparisons among Alley Cropping Treatments

In the first three seasons, the lowest maize yields were obtained with pruning at 0 and 30 DAP and the prunings were removed. In the fourth season, pruning at 0 and 40 DAP with removal of prunings gave lowest maize yields, although not significantly less than pruning at 0 and 30 DAP with prunings removed. Maize yields were also low in the first and third seasons in plots where pruning was done at 0 and 40 DAP and the prunings applied as mulch. These results may be attributed to several factors. With pruning at 0 and 30 DAP and removal of prunings, in addition to competition for nutrients and sometimes for water between the hedgerows and the maize, a partial shading of the crop by the hedgerows during it's later development stages contributed to reduced yield. In plots where the second pruning was made at 40 DAP, a longer period of competition during the vegetative stage combined with a partial shading of the crop by the hedgerows during it's later development stages are probably responsible for low yield.

HEDGEROW BIOMASS YIELDS

The utilization of prunings did not have a statistically significant effect on hedgerow biomass yields in any of the cropping seasons (Tables 3 and 5). However, cumulative leaf biomass production appeared to be slightly higher when the first pruning was incorporated into the soil (Figure. 6). Total, branch and stem biomass production were lower with three prunings than two (Tables 3 and 5). Similar results were reported by Duguma *et al.* (1988). However, cumulative leaf biomass production of the three cut regime was intermediate between that of the respective two-pruning regimes (Figure. 7). This is not significant and is due primarily to slightly higher (non-significant) initial yield with three-pruning regime in first season. The two-pruning regime with the second pruning at 40 days after maize planting was the most productive in total, leaf, branch and stem biomass yields in all four cropping seasons.

The fact that the total biomass declined after the first season does not means that biomass production is insufficient to maintain the system over time. The first pruning was made on leucaena hedgerows already two years old at start of the experiment. Consequently, more biomass was harvested in Season 1 than in subsequent prunings, but about two thirds of this biomass was stems and wood (Tables 3 and 5, Appendix Table A12). By considering the first six months after leucaena planting as establishment phase, the average yearly production with pruning at 0 and 40 DAP, 0 and 30 DAP, and 0, 30 and 60 DAP was computed at approximately 10.5, 9.3 and 9.2 metric tons total dry matter ha^{-1} $year^{-1}$ for the first year, respectively. For the same treatments, during the same period, the dry matter production of leaves and green stems combined amounted to 4.53, 3.96 and 4.10 t ha^{-1} $year^{-1}$, respectively.

In comparison with these values, a decline in total biomass was observed in 1994, the second year after cropping was begun. This was also true for leaves and green stems with the three-pruning regime. However, a slight increase in leaves and green stems was obtained in the second year with the two-pruning regimes. With second pruning at 40 DAP, combined leaf and green stem biomass production was 5.22 t ha^{-1} $year^{-1}$ and with second pruning at 30 DAP, it was 4.13 t ha^{-1} $year^{-1}$.

The apparent decline in leaf and stem production with the three-cut regime does not necessarily mean that this system is not sustainable. Sufficient time has not transpired to assess the long-term effects of the three-pruning regime on productivity of the system, especially in light of the variability in rainfall from season to season (Figure 1).

The trend for total biomass was unlike that observed by Shannon *et al.* (1994) who observed an increase over time. However, that trial began with newly planted hedgerows while this trial began with two-year old hedgerows. The amount of hedgerow biomass production is comparable to that found in the literature. The highest yields of total fresh biomass are similar to yields obtained by Shannon *et al.* (1994) in Zaire, while the leaf and green stem dry matter was similar to that reported in Nigeria by Duguma *et al.* (1988) for leucaena pruned at 50 cm height on a 2-3 month pruning cycle. In Haiti, Isaac *et al.* (1994) reported total dry weight biomass of around 9 t ha^{-1} $year^{-1}$ for leucaena hedgerows spaced at approximately 3.25 m apart on a soil derived from limestone parent material and pruned twice during each rainy season, or four times per year.

While biomass totaled for each cropping season provides a useful overview of the hedgerow production across seasons, timing of pruning with respect to crop development is also important. It is therefore important to know the amount of prunings available for application to the companion maize crop (and by inference the amount of nitrogen) at different stages of its development (Kang and Mulongoy, 1992). Information on individual harvests is presented in Appendix Tables A13-A16. Assuming a moderate concentration of N in leaves and branches of 3.33%, the highest yielding treatments (in terms of hedgerow biomass production) would have provided 119, 50 and 14 kg N ha^{-1} at 0, 30 and 60 DAP in Season 1, respectively (Table A13), and 33, 15 and 13 kg N ha^{-1} in Season 4 (Table A16). The amount provided in Season 1 is excellent for a normal maize crop, whereas in Season 4, it is low. However, the proportional distribution would appear to be satisfactory. Pruning at 0 and 40 DAP provided at least 118 and 53 kg ha^{-1} in Season 1 and 60 and 33 kg ha^{-1} in Season 4. In the absence of competition, this would have been preferable in terms of N fertility because of the greater amounts provided early in the season. However, competition of the hedgerows with the maize renders this treatment less preferable. Further testing is needed.

CONCLUSIONS

Although a longer series of data is necessary to be able to make definitive statements, the initial results are encouraging with respect to the suitability of alley cropping as a method of sustaining crop production under Haitian conditions. Whereas, in the stone wall control, the initial yields were higher than with alley cropping, within one year, there was no difference in yield between the two systems. Furthermore, yields in the stone wall treatment were on the decline, whereas under proper management, alley cropping yields remained relatively stable (Figure 5). The expectation, based upon results in Zaire (Shannon *et al.*, 1994) and Nigeria (Kang, 1993) is that with an additional year or two of cropping, alley cropped plots will prove definitely superior to control plots in terms of crop yields. This is by no means certain, however, given the shallow soil at the trial site, which confines the leucaena and maize roots to the same limited volume of soil. Further testing is therefore needed.

With respect to hedgerow management, the conclusions are readily apparent in Figure 8, which gives crop and hedgerow yields in the fourth season. Application of the prunings to the soil resulted in double the crop yield. Highest biomass yields are obtained with two prunings, at planting and 40 days later, but at the expense of lower maize yields. Highest maize yields are obtained with a three-pruning regime, with the prunings applied to the soil as mulch or incorporated.

IMPLICATIONS FOR HAITIAN FARMERS

Many farmers do not yet use hedgerows as a soil conservation measure. Rock walls are used by some farmers. While rock walls retain soil, they are inadequate to maintain soil fertility and sustain crop yields over an extended period. Alley cropping appears more promising from that standpoint.

A majority of Haitian farmers with hedgerows utilize all or a major portion of the leaf production of these hedgerows for livestock production. Removal of prunings from the plots without replacing organic matter and nutrients is not sustainable, as illustrated in Figure 3. Although the leaves of leucaena represent a high value to farmers, the long-term effect of their removal from the plots is to mine the soil. Strategies are needed to meet livestock requirements for feed as well as the need to maintain the productivity of cropped fields. This could be done by removing the leaves and returning livestock manure to the fields (a labor-intensive solution) or by planting high-value feed gardens and/or improved pasture.

IMPLICATIONS FOR PLUS EXTENSION

Prior to this study, PLUS did not have an objective means by which to formulate

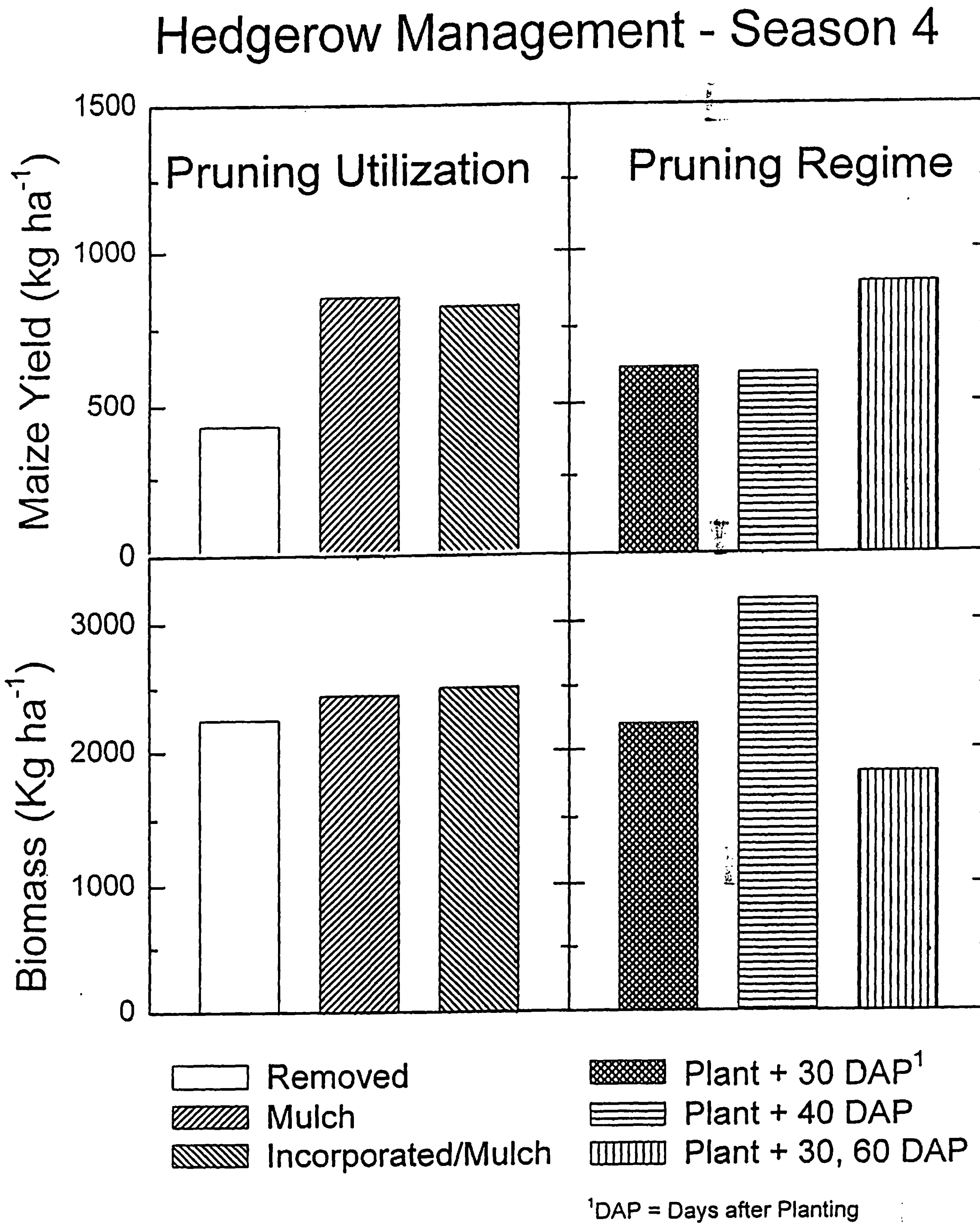


Figure 8. The effect of pruning use and timing of prunings on maize yield and hedgerow biomass production in fourth season.

recommendations on hedgerow management. This present study provides an objective basis for PLUS to make recommendations with respect to hedgerow management and use of hedgerow prunings.

The relative merits of promoting hedgerows as a soil conservation strategy as opposed to other strategies has been controversial among some elements in PLUS. Rock walls are effective in saving soil. However, rock walls are not able to sustain crop yields without some means to maintain soil organic matter and fertility. If there is to be a prioritization of intervention practices, it should be in favor of alley cropping.

The emphasis in PLUS has been on number of meters of hedgerows established. This trial clearly shows that hedgerow management has a major impact on both crop yield and biomass production. The extension messages given to farmers need to contain advice on management of the hedgerows.

Although more remains to be learned, it is clear that 1.) prunings must be applied to the soil if crop yields are to be sustained, and 2.) timeliness of pruning is essential to minimize competition to the crop and to ensure that nutrients from the decomposing prunings are available when needed by the crop. At the present time, we do not have adequate data to make a firm recommendation, but in the interim, a provisional recommendation can be made. At a minimum, two prunings per cropping season are needed, one at planting time and once within 30 - 40 days. Given the opposite effects of the third pruning on crop and biomass yields, the following recommendation would appear to be reasonable for maize, pending more precise field and economic data: if the hedgerow is growing quickly, such that it is likely to reduce maize growth, it should be pruned at 30 and 60 DAP; if the hedgerow is growing slowly, the second pruning can be delayed to 40 days without a third pruning.

Given the high value given to hedgerows for their feed production, strategies must be devised for providing farmers with alternate sources of livestock feed. These could involve removing part of the biomass as feed and returning livestock manure in its place, or establishment of feed gardens of leucaena, herbaceous perennial legumes and forage grasses in areas less suited to production of annual crops.

IMPLICATIONS FOR SECID/AUBURN

Further data is required to determine the long-term effects of different pruning regimes. A particular concern arising out of the present study is whether the three-pruning system will continue to produce sufficient biomass to sustain production. With respect to incorporation vrs. surface application of the prunings, the present data suggests that the possible benefit does not justify the added effort of incorporation. Furthermore, surface application protects the surface from erosion. Long-term results may show a more clear response to incorporation.

Data is needed as to the true amount of N being harvested with the various pruning regimes, in order to determine if the quantities produced under the various pruning regimes is adequate for producing satisfactory crop yields. Although we have attempted to estimate N production based upon values found in the literature, these values vary by as much as 100 %. Samples of all harvests have been retained and these should be analyzed for N content.

An economic analysis by the SECID Agricultural Economist would be useful in estimating the economic merits of alternate uses of prunings and different pruning regimes. Labor data is now available from the M&E Case Studies. The value of leucaena cuttings as livestock feed has also been estimated. A financial assessment based upon the combination of farm and trial data would require little effort and would provide important insights.

In the Monitoring and Evaluation hedgerow studies, greater attention needs to be paid to the management given to hedgerows by the farmers under study, as the management provided may be determinant in the outcomes. Specifically, number and timing of prunings and the use made of prunings should be reported in each case. Where the hedgerows are browsed, information on time of year, duration and intensity of browsing should be reported.

Refinement of pruning recommendations is needed with respect to the variety of growing conditions in Haiti as well as for other important crops. The research to date has been done with maize as the indicator crop. Information is required on the effects of hedgerow management regimes on other traditional crops in Haiti, such as sorghum, cassava, beans, pigeon peas, sweet potatoes, yams, etc. This suggests the need for simplified adaptive trials in other regions of the country.

Given the crucial influence of ruminants on farmer management and use of hedgerows, on-farm research is needed on alternative means to meet livestock forage needs. These could involve cycling hedgerow prunings through livestock and returning the manure to the alleys, or provision of other fodder sources in order to reserve hedgerow prunings for the crop.

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APPENDIX I

FIELD PLAN AND CROPPING HISTORY

Space between Hedgerows : 4 m   Distance between Plants : 10 cm

Plot size : 6.5 m x 8.0 m

<u>TREATMENTS</u>: PRUNING UTILIZATION X PRUNING REGIME

REMOVED

T1. Planting, 30 DAP
T2. Planting, 40 DAP
T3. Planting, 30 DAP, 60 DAP

MULCH

T4. Planting, 30 DAP
T5. Planting, 40 DAP
T6. Planting, 30 DAP, 60 DAP

Incorporated / Mulch

T7. Planting, 30 DAP
T8. Planting, 40 DAP
T9. Plan ing, 30 DAP, 60 DAP

T10. Control, stone wall

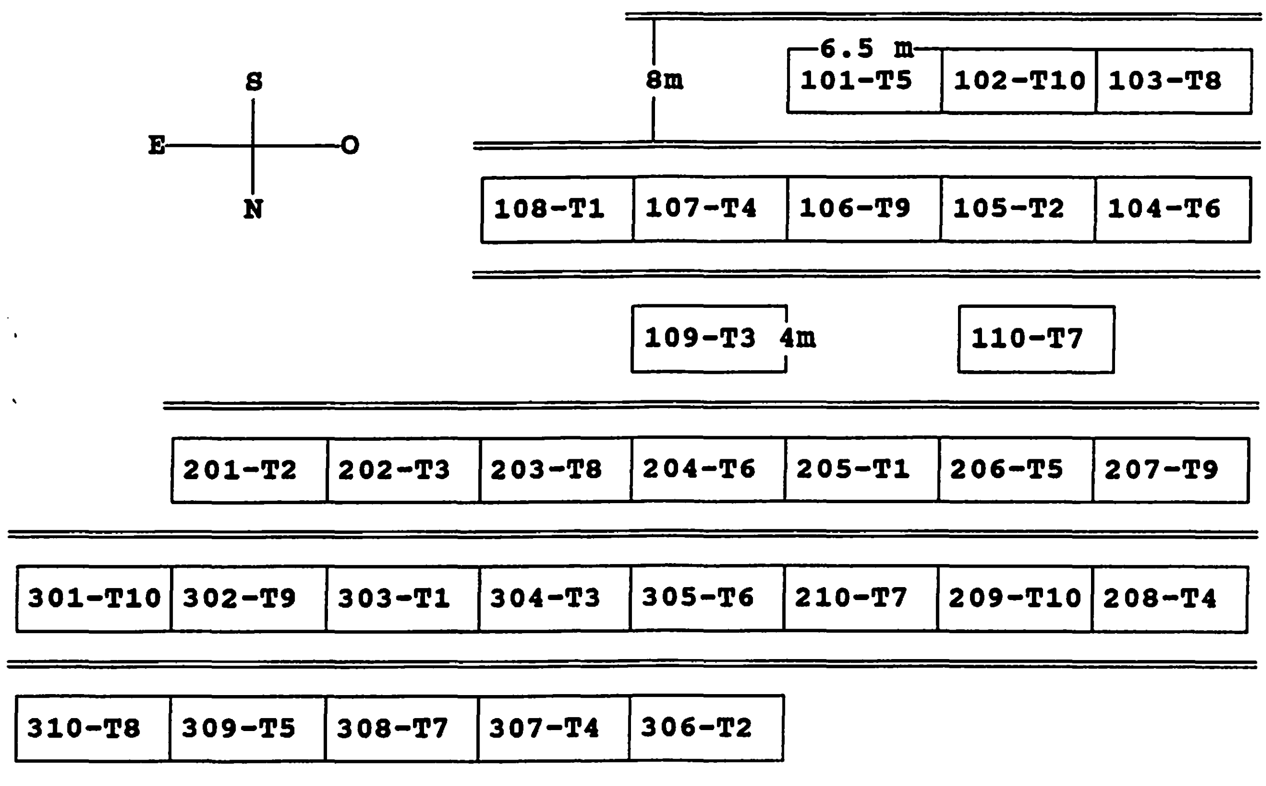

Fig. A1. Plot layout at Pernier. Agroforestry Adaptive Trial 2

Table A1. Cropping History of the site at Pernier.

Year	First Season (March - June)	Second Season (Sept. - December)
1980	Pasture†	Pasture
1981	Maize + Manioc + Pigeon Pea	Sweet potato + Carrots Manioc + Pigeon Pea
1982	Maize + Manioc + Pigeon Pea	Sweet potato + Carrots Manioc + Pigeon Pea
1983	Maize	Carrots
1984	Maize	Carrot (+ Lima bean)‡
1985	Maize	Carrot (+ Lima bean)‡
1986	Pasture	Carrot + Sweet potato
1987	Pasture	Carrot
1988	Pasture	Carrot
1989	Pasture	Carrot + Lima bean
1990	Pasture	Carrot + Lima bean

† Tethered cattle, horses and burros

‡ A few scattered plants in field and along borders

APPENDIX II

ADDITIONAL MEASUREMENTS TAKEN ON MAIZE CROP

FRESH WEIGHT OF EARS

Ear weight is important as a component of yield and also in the sale of fresh maize. Since the general conclusions differ little from that of grain yield, discussion of ear weight will be dropped in the interest of time and space. The data on ear weight are presented in Tables A2 and A3 for future reference.

NUMBER OF EARS

The number of ears harvested is also an important parameter in the evaluation of maize yields. It provides information on the performance or the potential of the material in study under specific conditions.

Effect of Pruning Use

Application of prunings to the soil significantly increased the number of ears harvested in three seasons. (Table A2). The differences between application and removal were greater in the last two cropping seasons. There was no significant differences between mulching and incorporation, although the trend was for more maize ears with incorporation of the first pruning.

Effect of Timing of Pruning

The three-pruning regime resulted in greater number of ears than the two-pruning regimes in all four seasons (Table A2). There were no significant differences between the two-pruning regimes except in the second season, when a second pruning at 40 days resulted in more ears harvested than when pruned at 30 days.

Table A2. Number of maize ears harvested and fresh weight of ears in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

	Ears Harvested/seasons[†]				Yield of Ears/seasons			
Factors	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	#/plot				t/ha			
Pruning Utilization								
Removed	34.77	37.67	26.77	23.47	0.80	0.74	0.64	0.55
Mulch	37.57	40.10	35.13	36.00	1.11	0.92	0.97	1.06
Incorporated/Mulch[‡]	40.80	40.43	39.23	37.00	1.08	0.98	1.01	1.03
Orthogonal Comparisons								
Removed vs Applied	*	ns	***	***	**	**	***	***
Mulch vs Incorp.	ns	ns	ns	ns	ns	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[§]	35.90	36.33	30.77	31.33	0.87	0.72	0.74	0.80
Planting + 40 DAP	35.30	40.57	31.13	29.00	0.77	0.86	0.75	0.73
Planting + 30+60 DAP	41.90	41.30	39.23	36.13	1.35	1.06	1.13	1.10
Orthogonal Comparisons								
3 vs 2 Prunings	***	ns	***	*	***	***	***	***
30 vs 40 DAP	ns	**	ns	ns	ns	ns	ns	ns

[†]/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

[‡]/ Pruning incorporated at planting, mulch thereafter; [§]/ DAP = Days after planting.

ns, *, **, *** = Not significant, significant at the 5 %, 1 % and 0.5 % levels of probability, respectively.

Stone Wall vrs. Hedgerows

More ears were produced in the stone wall control plots than in other plots in all seasons (Table A3). However, the difference between the control and the best alley cropping treatments was not significant in the last two seasons. The larger number of ears in the control plots compared to alley plots reflects the larger number of plants in control plots. Five rows of maize were sown in control plots compared to four in alley plots (Figure 1). In Season 4, there was no significant difference between the number of ears harvested in the control plots and the mean of alley cropping treatments where prunings were applied to the soil.

Comparisons Among Alley Cropping Treatments

After the control, the treatments of three prunings with prunings applied, either as mulch or incorporation of first pruning, gave the most ears, with no significant differences between them (Table A3).

Interactions

The interaction between pruning use and pruning regime was significant ($P < 0.005$) in the first and third seasons. Where prunings were removed, the largest numbers of ears were harvested with a pruning regime of 0 and 40 DAP, whereas when prunings were applied to the soil, this pruning regime gave the lowest number of ears (Table A3).

Time Trend

When prunings were removed from the plots, ear numbers appeared to decline in the third and fourth seasons (Table A2), whereas numbers appeared to be more stable across seasons when the prunings were applied to the soil. In control plots, number of ears decreased by 25 % over the 4 seasons (Table A3). Since the production in the best alley treatments remained nearly stable over the four seasons, there was almost no

Table A3. Number of ears harvested and fresh weight of ears in first four cropping seasons. Agroforestry Adaptive Trial II.

	Ears Harvested/seasons[†]				Yield of Ears/seasons			
Treatments	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	#/Plot				t/ha			
Removed								
Planting + 30 DAP[‡]	25.0	32.0	16.3	24.7	0.40	0.52	0.29	0.52
Planting + 40 DAP	39.3	41.7	33.0	16.7	0.96	0.85	0.81	0.42
Planting + 30+60 DAP	40.0	39.3	31.0	29.0	1.03	0.86	0.81	0.70
Mulch								
Planting + 30 DAP	40.7	37.7	37.0	35.0	1.19	0.80	0.96	0.97
Planting + 40 DAP	29.0	39.3	24.7	32.3	0.54	0.79	0.56	0.88
Planting + 30+60 DAP	43.0	43.3	43.7	40.7	1.59	1.18	1.39	1.33
Incorporated/Mulch[§]								
Planting + 30 DAP	42.0	39.3	39.0	34.3	1.01	0.83	0.97	0.91
Planting + 40 DAP	37.7	40.7	35.7	38.0	0.80	0.95	0.87	0.90
Planting + 30+60 DAP	42.7	41.3	43.0	38.7	1.43	1.15	1.19	1.28
Control (Dry Wall)	55.0	53.0	50.7	41.0	2.12	1.55	1.45	1.15
Significance (F test)	***	***	***	***	***	***	***	***
$LSD_{0.05}$	8.0	5.2	9.4	10.0	0.41	0.30	0.38	0.41
CV %	11.8	7.5	15.5	17.7	21.59	18.46	23.68	26.26

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ DAP = Days after planting; §/ Pruning incorporated at planting, mulch thereafter.

*** = Significant at 0.5 % level of probability.

difference in ear number between these treatments and the control despite a 20 % lower plant population.

FERTILE PLANTS

The percentage of fertile and sterile plants is an important indicator of stress experienced by maize plants.

Effect of Pruning Use

Effects of pruning utilization on percent fertile plants was limited. Removal of prunings resulted in significantly lower percentages of fertile plants in the third and fourth seasons (Table A4). This is probably associated with the decline in soil fertility resulting from continuous cultivation without replacement of plant nutrients and organic matter. There were no significant differences between the two modes of pruning application.

Effect of Timing of Prunings

Pruning regime affected percent fertile plants in all seasons. The percentage of fertile plants was higher with three prunings than with two prunings, except in the second season, when no difference was observed (Table A4). In the second season, a higher percentage of fertile plants was observed with a second cut at 40 days, as opposed to 30 days. In the other seasons, there were no significant differences between the two-pruning regimes.

Stone Wall vrs. Alley Cropping

The percentage of fertile plants in control (stone wall) plots did not differ significantly from that in alley plots that yielded the highest (Table A5). It was higher than where the prunings were removed from the plots. Although not statistically significant, higher % fertile plants in Seasons 3 and 4 were observed in maize plants in

Table A4. Percent fertile and lodged plants in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

	Fertile Plants/seasons[†]				Lodged Plants/seasons			
Treatments	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	%							
Pruning Utilization								
Removed	83.0	85.7	73.0	64.7	4.8	7.2	2.7	12.1
Mulch	84.5	89.8	80.7	88.9	4.9	5.9	3.3	12.0
Incorporated/Mulch[‡]	93.6	91.9	86.0	87.6	2.8	3.6	4.2	13.3
Orthogonal Comparisons								
Removed vs Applied	ns	ns	*	***	ns	*	ns	ns
Mulch vs Incorp.	ns	ns	ns	ns	ns	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[§]	83.1	83.0	75.0	79.7	4.7	6.2	2.3	7.0
Planting + 40 DAP	81.5	92.8	74.2	70.4	5.7	7.2	4.6	14.5
Planting + 30+60 DAP	96.4	91.6	90.5	91.0	2.1	3.3	3.2	16.0
Orthogonal Comparisons								
3 vs 2 Prunings	***	ns	***	*	**	***	ns	ns
30 vs 40 DAP	ns	***	ns	ns	ns	ns	ns	ns

[†]/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.
[‡]/ Pruning incorporated at planting, mulch thereafter; [§]/ DAP = Days after planting.
ns, *, **, *** = Not significant, significant at the 5 %, 1 % and 0.5 % levels of probability, respectively.

Table A5. Percent fertile and lodged plants in first four cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Fertile Plants/seasons[†]				Lodged Plants/seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	%							
Removed								
Planting + 30 DAP[‡]	61.9	74.0	55.7	67.4	4.1	9.4	0.0	7.3
Planting + 40 DAP	91.8	94.6	77.3	44.6	8.7	8.4	4.7	18.3
Planting + 30+60 DAP	95.1	88.4	85.9	82.0	1.7	3.8	3.3	10.8
Mulch								
Planting + 30 DAP	94.2	85.3	86.0	88.5	5.5	7.6	3.3	7.8
Planting + 40 DAP	62.8	90.0	64.0	82.9	6.2	7.8	3.1	9.4
Planting + 30+60 DAP	96.5	94.2	92.2	95.3	3.1	2.2	3.4	18.8
Incorporated/Mulch[§]								
Planting + 30 DAP	93.2	89.8	83.3	83.1	4.6	1.5	3.6	5.8
Planting + 40 DAP	90.0	93.7	81.3	83.8	2.3	5.5	6.0	15.9
Planting + 30+60 DAP	97.7	92.3	93.3	95.8	1.6	3.8	3.0	18.3
Control (Dry Wall)	94.4	88.7	88.8	87.1	5.0	7.2	5.4	22.5
Significance (F test)	***	ns	*	*	ns	**	ns	ns
$LSD_{0.05}$	16.4	10.8	20.3	24.3	4.5	4.5	5.1	13.3
CV %	10.9	7.1	14.7	17.5	61.1	45.9	83.0	57.4

[†/] 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

[‡/] DAP = Days after planting; [§/] Pruning incorporated at planting, mulch thereafter.

ns, *, **, *** = Not significant, significant at the 5 %, 1 % and 0.5 % levels of probability, respectively.

the three-pruning regime with prunings applied to the soil than in the stone wall control.

Comparisons among treatments

Excellent percentage of fertile plants (> 92 %) was obtained with the three-pruning regime where the prunings were applied to the soil as mulch or incorporated (Table A5). Good results (> 80 %) were recorded with other treatments except in the first and third season where the prunings were applied as mulch at planting and 40 DAP, and where prunings were removed at planting and 30 DAP. The lowest percent of fertile plants, 44.6 %, was obtained in the fourth season when the prunings were removed from the plots at planting and 40 DAP (Table A5).

Interactions

Significant interactions ($P < 0.005$) between pruning use and timing of application were obtained for fertile plants during the first season.

LODGED PLANTS

Lodging occurs when plants fall or bend over. This is an undesirable trait which can result in possible yield loss and/or damage to harvested grain, especially if the ears touch the ground. Conversely, lodging may also be a function of high yield as the weight of ears increases the likelihood of lodging. Lodging can also result from poor or elongated stem development as occurs with shading and poor plant nutrition.

Effect of Pruning Use

Effects of pruning utilization on percent lodging was limited. Removal of prunings resulted in a slightly higher percentage lodging in the second season (Table A4). There were no significant differences between the two modes of pruning application.

Effect of Timing of Prunings

Less lodging was observed with three prunings than with two during the first two seasons (Table A4), but no significant differences were observed in the third and fourth seasons. There were no differences between the two-pruning regimes. Increased lodging with the two-pruning regime may be related to shading by the hedgerows.

Stone Walls vrs. Alley Cropping

Lodging in the control (stone wall) plots was in the range of that observed in alley cropped plots, but tended to be within the high range (Table A5). There were no significant differences between lodging in control and alley plots in the first three seasons. In the fourth season, higher lodging was observed in the control than in the alley treatments, when considered as a group, but the control did not differ from the highest yielding alley treatments.

Comparisons among Alley Treatments

The percentage of lodged plants was generally low during the first three seasons, with three-pruning regime giving the lowest lodging (Table A5). During the fourth season, lodging was higher, but no significant trends were observed (Tables A4, A5).

Interactions

There were no significant interactions for lodged plants in any of the four cropping seasons.

MAIZE HEIGHT

Maize height is a good measure of the health of the plant over the vegetative stage of the season, and is less subject than grain yield to the influence of conditions specifically during flowering and grain filling stages.

Effect of Pruning Use

Maize plants were taller where the prunings were applied to the soil than where the prunings were removed from the plots (Table A6). Incorporation of first pruning gave slightly taller maize plants than application as mulch, but these differences were not statistically significant. Tallest maize plants were recorded in the first growing season while the shortest maize plants were produced in the third season and specially where prunings removed (average of 92.03 cm).

Effect of Timing of Pruning

Maize plants were significantly taller in the first season with a three-pruning regime than with two prunings (Table A6). Although not significant, the trend was also evident in subsequent seasons.

Stone Wall vrs. Alley Cropping

The control plots produced tallest maize plants during the first three seasons. In the fourth season, there was no difference between the control and other treatments.

Comparisons among Alley Cropping Treatments

At the first and third season, the control was followed by the mulch treatment with two prunings at planting and 30 DAP (Table A7). In the second season, the treatment of three-pruning regime with incorporation of first pruning ranked second. In the fourth season, though not significant, the tallest maize plants were produced by three prunings where the first pruning was incorporated, followed by the three mulch treatments. In all seasons, plants were shortest when the prunings were removed from the plots at planting and 30 DAP (Table A7).

Table A6. Maize height and grain moisture at harvest in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

Factors	Maize height/Seasons[†]				Grain Moisture/Seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	cm				%			
Pruning Utilization								
Removed	105.44	100.39	92.03	100.75	15.06	18.39	12.50	17.10
Mulch	119.56	110.30	102.01	112.75	15.50	19.63	12.66	17.11
Incorporated/Mulch[‡]	120.12	112.28	103.66	113.00	14.68	19.68	12.62	16.50
Orthogonal Comparisons								
Removed vs Applied	***	*	***	**	ns	*	ns	ns
Mulch vs Incorp.	ns	ns	ns	ns	*	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[§]	116.04	103.49	96.69	106.93	14.84	18.48	12.47	17.00
Planting + 40 DAP	108.28	106.74	99.42	108.57	14.91	19.26	12.91	16.42
Planting + 30+60 DAP	120.80	111.74	101.57	110.99	15.49	19.96	12.41	17.28
Orthogonal Comparisons								
3 vs 2 Prunings	*	ns	ns	ns	*	ns	ns	*
30 vs 40 DAP	ns	ns	ns	ns	ns	ns	ns	ns

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Pruning incorporated at planting, mulch thereafter; §/ DAP = Days after planting.

ns, *, **, *** = Not significant, significant at the 5 % and 1 % and 0.5 % levels of probability, respectively.

Table A7. Maize height and grain moisture at harvest in first four cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Maize height/Seasons[†]				Grain Moisture/Seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	------------- cm -------------				------------- % -------------			
<u>Removed</u>								
Planting + 30 DAP[‡]	94.62	91.66	80.12	97.99	14.68	17.38	11.78	16.95
Planting + 40 DAP	111.73	105.52	101.65	101.31	15.17	18.83	13.33	17.05
Planting + 30+60 DAP	109.97	104.00	94.24	102.95	15.32	18.96	12.39	17.29
<u>Mulch</u>								
Planting + 30 DAP	129.39	113.09	106.74	113.08	15.45	20.01	12.99	17.73
Planting + 40 DAP	103.29	105.04	93.22	114.38	14.71	18.32	12.50	16.34
Planting + 30+60 DAP	126.01	112.77	106.08	110.78	16.33	20.56	12.49	17.25
<u>Incorporated/Mulch</u>[§]								
Planting + 30 DAP	124.11	105.72	103.20	109.73	14.38	18.05	12.63	16.34
Planting + 40 DAP	109.82	109.65	103.39	110.02	14.84	20.62	12.90	15.87
Planting + 30+60 DAP	126.42	118.46	104.40	119.24	14.82	20.37	12.34	17.30
Control (Dry Wall)	137.44	130.87	114.14	110.69	15.97	22.09	12.65	16.81
Significance (F test)	***	*	***	ns	*	***	ns	ns
LSD $_{0.05}$	16.5	16.2	3.1	16.0	1.1	2.3	1.3	1.3
CV %	8.19	8.63	7.57	8.55	4.02	6.93	6.06	4.60

[†]/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

[‡]/ DAP = Days after planting; [§]/ Pruning incorporated at planting, mulch thereafter.

ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

Interactions

Significant interactions ($P < 0.05$) were obtained between pruning use and timing factors for maize plant heights during the first and third cropping seasons. When prunings were removed, pruning at 0 and 40 DAP resulted in taller plants than pruning at 0 and 30 DAP (Table A7). The reverse was the case when the prunings were applied to the soil.

GRAIN MOISTURE

Effect of Pruning Use

Differences in grain moisture among treatments of pruning utilization were significant during the first two cropping seasons. Application of prunings to the soil resulted in higher moisture content in the second season (Table A6). Except for the second season, higher percent grain moisture were recorded for plots where leucaena prunings were applied to the soil as mulch as opposed to incorporation (Table A6), but the difference was significant only in the first season.

Percent of grain moisture in seasons A (first and third cropping seasons) was generally lower than that in the respective cooler seasons B (second and fourth seasons).

Effect of Timing of Pruning

Higher grain moisture was observed with a three-pruning regime than with two-pruning regimes during the first and fourth seasons (Table A6). Between the two-pruning regimes, there were no significant differences in grain moisture in any of the four cropping seasons.

Stone Wall vrs. Alley Cropping

In the first and second seasons, grain moisture in the control plots ranked second and highest, respectively (Table A7). There were no significant differences in the last two seasons.

Comparisons among treatments

With respect to maize grain moisture, significant differences among the treatments were observed during the first two and last seasons. However, over the seasons, the results were not consistent.

Interactions

There were no significant interactions for grain moisture in any of the four growing seasons.

MAIZE STAND COUNTS

Stand counts did not differ significantly in three of the four seasons with each of the two factors, pruning utilization and pruning regime (Table A8). Stand loss, however, was greater under the treatments where prunings were removed from the plots in all seasons. The higher loss of plants with removal of prunings was significant at harvest in the fourth season.

As expected, the control treatment with five rows of maize, gave significantly higher stands in all seasons (Table A9). However, for the other treatments, maize stands were not greatly affected by individual treatments, except for the removal of prunings.

There were no significant interactions between pruning use and pruning regime at any of the four growing seasons for stand counts.

Table A8. Maize stand counts in first four cropping seasons. Main effect of factors. Agroforestry Adaptive Trial II.

Factors	Season[†] 93-A		Season 93-B		Season 94-A		Season 94-B	
	Count 1[‡]	Count 2[$]	Count 1	Count 2	Count 1	Count 2	Count 1	Count 2
	#/Plot							
Pruning Utilization								
Removed	65.0	61.3	64.2	62.4	64.7	61.3	54.9	48.5
Mulch	65.1	62.8	64.8	62.4	66.1	63.0	56.0	53.7
Incorporated/Mulch[¶]	66.1	64.6	66.4	64.7	66.3	62.7	58.4	56.2
Orthogonal Comparisons								
Removed vs Applied	ns	ns	ns	ns	*	ns	ns	*
Mulch vs Incorp.	ns	ns	ns	ns	ns	ns	ns	ns
Pruning Regime								
Planting + 30 DAP[††]	65.6	64.0	64.3	62.6	65.8	62.2	55.9	53.1
Planting + 40 DAP	65.5	62.5	65.5	63.3	66.6	63.4	54.5	50.9
Planting + 30+60 DAP	64.1	62.2	65.6	63.6	64.8	61.3	58.9	54.3
Orthogonal Comparisons								
3 vs 2 Prunings	ns	ns	ns	ns	*	ns	ns	ns
30 vs 40 DAP	ns	ns	ns	ns	ns	ns	ns	ns

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Count after thinning; $/ Count at harvest; ¶/ DAP = Days after planting. ††/ Pruning incorporated at planting, mulch thereafter.

ns, * = Not significant, significant at the 5 % level of probability, respectively.

Table A9. Maize stand counts in first four cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Season[†] 93-A		Season 93-B		Season 94-A		Season 94-B	
	Count 1[‡]	Count 2[§]	Count 1	Count 2	Count 1	Count 2	Count 1	Count 2
	#/Plot							
Removed								
Planting + 30 DAP[¶]	66.7	62.7	63.0	61.7	64.7	60.7	56.0	51.7
Planting + 40 DAP	65.3	61.0	65.0	64.3	65.0	63.3	51.0	44.7
Planting + 30+60 DAP	63.0	60.3	64.7	61.3	64.3	60.0	57.7	49.0
Mulch								
Planting + 30 DAP	65.3	63.0	62.7	60.7	65.0	62.3	53.0	51.0
Planting + 40 DAP	67.0	64.3	65.3	61.7	67.7	62.7	55.3	53.0
Planting + 30+60 DAP	63.0	61.0	66.3	64.7	65.7	64.0	59.7	57.0
Incorporated/Mulch[††]								
Planting + 30 DAP	67.7	66.3	67.3	65.3	67.7	63.7	58.7	56.7
Planting + 40 DAP	64.3	62.3	66.3	64.0	67.0	64.3	57.3	55.0
Planting + 30+60 DAP	66.3	65.3	65.7	64.7	64.3	60.0	59.3	57.0
Control (Dry Wall)	84.7	80.7	82.7	80.0	84.0	81.3	74.3	70.0
Significance (F test)	***	***	***	***	***	***	ns	*
$LSD_{0.05}$	4.9	7.0	3.3	4.4	2.7	4.3	13.6	12.82
CV %	4.2	6.3	2.9	4.0	2.3	3.9	13.6	13.71

[†]/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.
[‡]/ Count after thinning; [§]/ Count at harvest; [¶]/ DAP = Days after planting; [††]/ Pruning incorporated at planting, mulch thereafter.
ns, *, *** = Not significant, significant at the 5 % and 0.5 % levels of probability, respectively.

APPENDIX III

SUPPLEMENTARY DATA ON HEDGEROW BIOMASS

Table A10. Total and leaf fresh weight biomass in four cropping seasons. Agroforestry Adaptive Trial II.

	Total/Seasons[†]				Leaf/Seasons			
Treatments	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Removed								
Planting + 30 DAP[‡]	27.51	10.02	6.27	5.22	8.18	5.88	3.84	3.05
Planting + 40 DAP	39.58	13.44	7.66	8.83	10.60	7.54	4.64	5.32
Planting + 30+60 DAP	31.03	9.30	5.68	5.51	9.92	6.24	4.31	3.99
Mulch								
Planting + 30 DAP	35.10	11.81	7.64	6.65	9.64	6.54	4.36	3.73
Planting + 40 DAP	32.83	12.90	7.07	8.47	9.57	7.48	4.17	5.21
Planting + 30+60 DAP	34.79	9.74	5.82	5.57	10.07	6.45	4.25	4.04
Incorporated/Mulch[§]								
Planting + 30 DAP	29.26	11.64	7.30	5.65	7.94	6.60	4.35	3.31
Planting + 40 DAP	36.91	14.20	8.64	10.03	10.85	8.34	4.97	5.97
Planting + 30+60 DAP	35.43	9.42	6.40	5.89	10.55	6.26	4.69	4.27
Significance (F test)	*	*	ns	**	ns	ns	ns	*
$LSD_{0.05}$	9.87	2.98	1.88	2.38	3.00	1.58	0.99	1.48
CV %	16.97	15.12	15.63	19.99	17.85	13.36	12.95	19.76

†/ 93-A = First rainy season, 24 March - 15 July, 1993; 93-B = Second rainy season, 25 August - 15 December, 1993;
94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ DAP = Days after planting; §/ Pruning incorporated at planting, mulch thereafter.

ns, *, ** = Not significant, significant at the 5 % and 1 % levels of probability, respectively.

Table A11. Branch and stem fresh weight biomass in four cropping Seasons. Agroforestry Adaptive Trial II.

Treatments	Branches/Seasons[†]				Stems[‡]/Seasons			
	93-A	93-B	94-A	94-B	93-A	93-B	94-A	94-B
	t/ha							
Removed								
Planting + 30 DAP[§]	4.32	3.08	1.76	1.88	14.16	1.06	0.62	0.26
Planting + 40 DAP	6.62	4.01	2.42	2.94	21.33	1.89	0.60	0.57
Planting + 30+60 DAP	5.14	2.76	1.29	1.39	15.48	0.30	0.08	0.13
Mulch								
Planting + 30 DAP	5.12	3.51	2.27	2.25	19.60	1.76	0.94	0.66
Planting + 40 DAP	5.11	3.81	2.06	2.58	17.63	1.61	0.78	0.67
Planting + 30+60 DAP	5.67	2.82	1.49	1.46	18.72	0.48	0.08	0.07
Incorporated/Mulch[¶]								
Planting + 30 DAP	4.57	3.60	2.19	1.96	16.31	1.44	0.68	0.38
Planting + 40 DAP	5.73	4.11	2.44	3.12	19.04	1.75	1.22	0.94
Planting + 30+60 DAP	5.64	2.78	1.51	1.50	18.51	0.37	0.20	0.12
Significance (F test)	***	**	**	***	ns	***	***	***
$LSD_{0.05}$	0.95	0.74	0.62	0.71	5.87	0.77	0.47	0.29
CV %	10.28	12.63	18.36	19.22	18.98	37.33	46.85	40.35

†/ Branches = Green stems < 1 cm; 93-A = First rainy season, 24 March -15 July, 1993; 93-B= 2nd rainy season, 25 Aug.-15 Dec. 1993; 94-A = First rainy season, 9 March - 7 July, 1994; 94-B = Second rainy season, 26 August 94 - 3 January, 1995.

‡/ Stems 1-5 cm (diameter); §/ DAP = Days after planting; ¶/ Pruning incorporated at planting, mulch thereafter.

ns, **, *** = Not significant, significant at the 1 % and 0.5 % levels of probability, respectively.

Table A12. Wood and pod biomass production in the first cropping seasons. Agroforestry Adaptive Trial II.

Treatments	Fresh Weight		Dry Weight	
	Wood[†]	Pod	Wood	Pod
	t/ha			
Removed				
Planting + 30 DAP[‡]	0.45	0.40	0.28	0.27
Planting + 40 DAP	0.54	0.48	0.32	0.32
Planting + 30+60 DAP	0.00	0.49	0.00	0.32
Mulch				
Planting + 30 DAP	0.33	0.39	0.21	0.30
Planting + 40 DAP	0.00	0.52	0.00	0.30
Planting + 30+60 DAP	0.00	0.33	0.00	0.19
Incorporated/Mulch[§]				
Planting + 30 DAP	0.00	0.44	0.00	0.29
Planting + 40 DAP	0.49	0.81	0.27	0.54
Planting + 30+60 DAP	0.26	0.47	0.15	0.34
Significance (F test)	ns	ns	ns	ns
$LSD_{0.05}$	0.59	0.46	0.36	0.33
CV %	148.95	54.77	151.42	60.54

†/ Wood = Stems > 5 cm; ‡/ DAP = Days after planting; §/ Pruning incorporated at planting, mulch thereafter.
ns = Not significant.

Table A13. Total, leaf and green stems biomass production (t/ha) in the first cropping season. Agroforestry Adaptive Trial II.

Treatments	1st Cut (at planting) Total	Leaf	Branches[‡]	2nd Cut, at 30 or 40 DAP[†] Total	Leaf	Branches	3rd Cut (at 60 DAP) Total	Leaf	Branches
Fresh Weight Biomass									
Removed									
Planting + 30 DAP	23.08	5.21	2.87	4.43	2.98	1.45	.	.	.
Planting + 40 DAP	32.08	6.46	3.97	6.78	4.14	2.64	.	.	.
Planting + 30+60 DAP	24.57	5.48	3.12	4.99	3.35	1.64	1.47	1.09	0.38
Mulch									
Planting + 30 DAP	30.38	6.48	3.56	4.71	3.16	1.55	.	.	.
Planting + 40 DAP	27.41	6.16	3.10	5.42	3.42	2.01	.	.	.
Planting + 30+60 DAP	27.78	5.30	3.43	5.24	3.48	1.77	1.77	1.29	0.48
Incorporated/Mulch[§]									
Planting + 30 DAP	24.49	4.76	2.98	4.77	3.18	1.59	.	.	.
Planting + 40 DAP	30.72	6.93	3.45	6.19	3.92	2.29	.	.	.
Planting + 30+60 DAP	28.55	5.90	3.41	5.16	3.41	1.75	1.72	1.25	0.49
Dry Weight Biomass									
Removed									
Planting + 30 DAP	11.74	1.71	1.41	1.27	0.81	0.46	.	.	.
Planting + 40 DAP	16.33	2.15	1.90	1.98	1.12	0.86	.	.	.
Planting + 30+60 DAP	12.28	1.77	1.51	1.40	0.86	0.54	0.39	0.28	0.11
Mulch									
Planting + 30 DAP	15.58	2.13	1.71	1.28	0.81	0.47	.	.	.
Planting + 40 DAP	13.03	1.88	1.33	1.52	0.90	0.61	.	.	.
Planting + 30+60 DAP	14.09	1.80	1.64	1.54	0.97	0.57	0.45	0.32	0.13
Incorporated/Mulch									
Planting + 30 DAP	12.38	1.61	1.39	1.41	0.92	0.48	.	.	.
Planting + 40 DAP	15.07	2.23	1.62	1.67	0.98	0.69	.	.	.
Planting + 30+60 DAP	14.47	1.97	1.74	1.45	0.90	0.55	0.42	0.29	0.13

[†]/ DAP = Days after planting; [‡]Branches = Green stems < 1 cm

[§]/ Pruning incorporated at planting, mulch thereafter.

Table A14. Total, leaf and green stems biomass production (t/ha) in the second cropping season. Agroforestry Adaptive Trial II.

Treatments	Fresh Weight Biomass								
	1st Cut (at planting)			2nd Cut, at 30 or 40 DAP[†]			3rd Cut (at 60 DAP)		
	Total	Leaf	Branches[‡]	Total	Leaf	Branches	Total	Leaf	Branches
Removed									
Planting + 30 DAP	4.99	2.54	1.48	5.03	3.34	1.60	.	.	.
Planting + 40 DAP	5.97	2.95	1.70	7.47	4.59	2.31	.	.	.
Planting + 30+60 DAP	3.15	1.98	0.92	5.02	3.37	1.60	1.12	0.89	0.23
Mulch									
Planting + 30 DAP	6.49	3.17	1.69	5.32	3.37	1.82	.	.	.
Planting + 40 DAP	5.88	3.11	1.56	7.03	4.37	2.25	.	.	.
Planting + 30+60 DAP	3.39	2.02	0.96	5.00	3.36	1.57	1.36	1.07	0.29
Incorporated/Mulch[§]									
Planting + 30 DAP	5.79	2.90	1.61	5.84	3.70	1.99	.	.	.
Planting + 40 DAP	6.52	3.50	1.69	7.68	4.83	2.42	.	.	.
Planting + 30+60 DAP	3.36	2.02	1.06	4.98	3.36	1.54	1.07	0.89	0.18
	Dry Weight Biomass								
Removed									
Planting + 30 DAP	2.10	0.82	0.75	1.52	0.95	0.54	.	.	.
Planting + 40 DAP	2.42	0.95	0.78	2.13	1.21	0.74	.	.	.
Planting + 30+60 DAP	1.18	0.62	0.44	1.52	0.94	0.57	0.29	0.24	0.06
Mulch									
Planting + 30 DAP	2.73	1.01	0.79	1.57	0.92	0.61	.	.	.
Planting + 40 DAP	2.33	1.02	0.72	1.82	1.00	0.69	.	.	.
Planting + 30+60 DAP	1.25	0.61	0.45	1.43	0.88	0.52	0.34	0.26	0.08
Incorporated/Mulch									
Planting + 30 DAP	2.56	0.96	0.86	1.69	1.00	0.64	.	.	.
Planting + 40 DAP	2.54	1.11	0.74	2.07	1.17	0.77	.	.	.
Planting + 30+60 DAP	1.28	0.66	0.49	1.43	0.90	0.50	0.29	0.24	0.05

†/ DAP = Days after planting; ‡Branches = Green stems < 1 cm

§/ Pruning incorporated at planting, mulch thereafter.

Table A15. Total, leaf and green stems biomass production (t/ha) in the third cropping season. Agroforestry Adaptive Trial II.

Treatments	Fresh Weight Biomass								
	1st Cut (at planting)			2nd Cut, at 30 or 40 DAP[†]			3rd Cut (at 60 DAP)		
	Total	Leaf	Branches[‡]	Total	Leaf	Branches	Total	Leaf	Branches
Removed									
Planting + 30 DAP	4.01	2.18	1.17	2.26	1.67	0.59	.	.	.
Planting + 40 DAP	4.47	2.46	1.40	3.19	2.18	1.02	.	.	.
Planting + 30+60 DAP	2.22	1.51	0.62	2.34	1.78	0.56	1.12	1.02	0.11
Mulch									
Planting + 30 DAP	4.93	2.52	1.40	2.71	1.84	0.87	.	.	.
Planting + 40 DAP	4.64	2.47	1.34	2.43	1.70	0.73	.	.	.
Planting + 30+60 DAP	2.55	1.46	0.71	2.56	1.87	0.69	1.01	0.93	0.09
Incorporated/Mulch[§]									
Planting + 30 DAP	4.65	2.50	1.39	2.65	1.85	0.80	.	.	.
Planting + 40 DAP	5.98	3.14	1.62	2.65	1.83	0.82	.	.	.
Planting + 30+60 DAP	2.71	1.78	0.73	2.51	1.83	0.68	1.18	1.08	0.10
	Dry Weight Biomass								
Removed									
Planting + 30 DAP	1.54	0.71	0.52	0.64	0.48	0.16	.	.	.
Planting + 40 DAP	1.85	0.89	0.66	1.04	0.76	0.27	.	.	.
Planting + 30+60 DAP	0.80	0.50	0.26	0.67	0.51	0.16	0.27	0.25	0.03
Mulch									
Planting + 30 DAP	2.01	0.86	0.64	0.80	0.53	0.27	.	.	.
Planting + 40 DAP	1.88	0.85	0.63	0.70	0.49	0.21	.	.	.
Planting + 30+60 DAP	0.86	0.50	0.33	0.76	0.57	0.19	0.25	0.22	0.02
Incorporated/Mulch									
Planting + 30 DAP	1.85	0.86	0.63	0.74	0.52	0.22	.	.	.
Planting + 40 DAP	2.33	1.03	0.72	0.76	0.52	0.25	.	.	.
Planting + 30+60 DAP	0.98	0.59	0.30	0.72	0.54	0.18	0.29	0.27	0.03

†/ DAP = Days after planting; ‡Branches = Green stems < 1 cm

§/ Pruning incorporated at planting, mulch thereafter.

Table A16. Total, leaf and green stems biomass production (t/ha) in the fourth cropping season. Agroforestry Adaptive Trial II.

Treatments	1st Cut (at planting) Total	Leaf	Branches[‡]	2nd Cut, at 30 or 40 DAP[†] Total	Leaf	Branches	3rd Cut (at 60 DAP) Total	Leaf	Branches
Fresh Weight Biomass									
Removed									
Planting + 30 DAP	3.26	1.60	1.38	1.96	1.45	0.50	.	.	.
Planting + 40 DAP	4.93	2.53	1.83	3.90	2.79	1.11	.	.	.
Planting + 30+60 DAP	2.36	1.45	0.79	1.56	1.19	0.37	1.59	1.35	0.24
Mulch									
Planting + 30 DAP	4.83	2.36	1.81	1.82	1.37	0.45	.	.	.
Planting + 40 DAP	4.91	2.58	1.65	3.56	2.63	0.93	.	.	.
Planting + 30+60 DAP	2.51	1.55	0.90	1.49	1.19	0.30	1.57	1.30	0.27
Incorporated/Mulch[§]									
Planting + 30 DAP	3.94	2.01	1.55	1.71	1.30	0.40	.	.	.
Planting + 40 DAP	5.54	2.67	1.94	4.48	3.30	1.18	.	.	.
Planting + 30+60 DAP	2.73	1.70	0.91	1.54	1.20	0.34	1.62	1.37	0.25
Dry Weight Biomass									
Removed									
Planting + 30 DAP	1.33	0.58	0.61	0.59	0.43	0.16	.	.	.
Planting + 40 DAP	2.14	0.91	0.94	0.93	0.65	0.29	.	.	.
Planting + 30+60 DAP	0.89	0.50	0.34	0.48	0.36	0.12	0.38	0.33	0.05
Mulch									
Planting + 30 DAP	1.99	0.84	0.85	0.55	0.42	0.13	.	.	.
Planting + 40 DAP	2.07	0.97	0.77	0.87	0.62	0.25	.	.	.
Planting + 30+60 DAP	1.01	0.53	0.44	0.45	0.36	0.09	0.39	0.32	0.07
Incorporated/Mulch									
Planting + 30 DAP	1.62	0.70	0.74	0.53	0.40	0.13	.	.	.
Planting + 40 DAP	2.36	0.97	0.93	1.11	0.80	0.31	.	.	.
Planting + 30+60 DAP	1.06	0.59	0.41	0.47	0.37	0.10	0.38	0.32	0.06

[†]/ DAP = Days after planting; [‡]Branches = Green stems < 1 cm

[§]/ Pruning incorporated at planting, mulch thereafter.

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